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**National Highway
Traffic Safety
Administration**

Model Minimum Performance Specifications for Police Traffic Radar Devices

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16. Abstract This publication provides an overview of the circumstances leading to the International Association of Chiefs of Police request that the Federal Government become involved in the development of specifications for police traffic radar and the work that has been done since 1977 in response to that request. <u>Chapter 1</u> presents a succinct description of the status of police traffic radar and its use in speed limit enforcement. It also contains a description of the Federal government's involvement with police traffic radar since 1977 and contains NHTSA's recommendations concerning the use of these devices in speed enforcement. <u>Chapter 2</u> contains a discussion of the evolution of the performance specifications from a proposed rulemaking activity to publication in the form of model minimum specifications for police radar. <u>Chapter 3</u> provides the model minimum specifications together with recommended procedures with which radar devices may be tested to assess their compliance with the guidelines proposed in the specifications.			
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PREFACE

THIS DOCUMENT IS A REVISION OF THE "MODEL MINIMUM PERFORMANCE SPECIFICATIONS FOR POLICE TRAFFIC RADAR DEVICES" DOT HS 807-415, PUBLISHED IN MAY 1989. THE PRINCIPAL CHANGE IN THIS DOCUMENT IS THE INCLUSION OF SPECIFICATIONS AND TESTING PROTOCOLS FOR Ka BAND RADAR UNITS.

This document has been prepared for a number of audiences interested in police traffic radar. They include police agencies that use radar equipment to enforce speed laws and depend on the accuracy and reliability of radar evidence to support speeding citations, the legal community and the radar manufacturers. The report provides the reader with information about the research on police traffic radar completed by the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), under an Interagency Agreement with the National Highway Traffic Safety Administration (NHTSA).

There are three chapters in this document:

The first chapter provides an overview of the current status of police traffic radar for speed enforcement and it summarizes the Federal Government's activity in this area since 1977.

The second chapter discusses the processes that led to the development of the performance measures.

The third chapter presents the actual model specifications for police traffic radar, along with recommended procedures with which radar devices can be tested to assess whether they meet the proposed guidelines.

It is hoped that these model minimum specifications will assist law enforcement administrators in making more informed purchasing decisions.

CHAPTER 1

OVERVIEW

Police traffic radar has been used in this country to detect speeding motorists for about 40 years. During that time, radar speed measuring devices have evolved from the original bulky stationary models to the present compact and sophisticated units capable of monitoring the speed of vehicles moving in all directions while employed in either the stationary or moving mode. These technological advances have greatly enhanced the mobility, efficiency, and effectiveness of police traffic radar operations.

Despite the technological advances, highway safety and law enforcement administrators must ensure that radar operators receive adequate training, including recognition and avoidance of the electronic anomalies associated with such devices. Operators should be able to demonstrate their competence with the unit under varying conditions in supervised field performance tests. In addition, the radar manufacturing industry should continue to search for ways to improve the target identification capabilities of present radar devices.

The courts, as well as some radar critics, also have pointed out the need for State-level police guidance for police radar enforcement programs. After evaluation of present programs, highway safety and law enforcement officials should develop and implement comprehensive policies and procedures to ensure that police traffic radar is used properly and that traffic safety goals are achieved. State-level policy guidance would provide the added benefit of increased uniformity within a State and encourage statewide development of standard operating procedures. This would enhance voluntary compliance as the motorist travels through the many jurisdictions within each State.

NHTSA has sponsored three programs which should upgrade both the reliability and credibility of police traffic radar equipment and the quality of operator training.

Equipment:

In August 1977, NHTSA entered into an Interagency Agreement with the Law Enforcement Standards Laboratory of the National Bureau of Standards (NBS - now the National Institute of Standards and Technology, NIST) to develop performance standards for police speed measuring devices. NBS tested most of the police radar speed measuring devices used in this country and developed comprehensive performance requirements for these speed measuring devices. The draft performance standards for radar devices were completed and delivered to NHTSA in December 1980. On January 8, 1981, these specifications appeared as a proposed rulemaking in the Federal Register 46 FR 2097. Nineteen comments were received and reviewed in response to the proposed rule. The comments that were appropriate were synthesized into the model radar specifications which are presented later in this report.

NBS also determined that there were certain operational situations which may lead an inattentive or untrained operator to obtain an incorrect reading or to associate the speed indicated on the radar devices with the wrong vehicle. NBS also pointed out the potential for obtaining an erroneous reading on a target vehicle under certain conditions when the radar unit is operated in the moving mode. Judgmental errors may occur if police radar operators do not understand and avoid the specific circumstances which give rise to these anomalies.

It also became clear that police administrators must ensure that radar devices are properly maintained and periodically tested and calibrated. Written policy defining maintenance and calibration procedures should be established in each agency. The procedures should define the conditions under which each device should be calibrated at a recognized testing facility. As a minimum, we recommend that each radar unit be tested for measurement accuracy every 1 to 3 years and on each occasion that the unit undergoes repair. A written policy should specify that accurate maintenance, repair, and calibration records for each device be established and maintained by the agency. These records should be available to the courts, whenever necessary, to verify the proper maintenance and calibration of the device.

NHTSA also sponsored a parallel effort to measure the microwave field strengths surrounding 22 models in use. The purpose of these measurements was to determine whether the microwave field strengths fell within the exposure limits set by the Occupational Safety and Health Act (OSHA). This effort was also undertaken in response to an International Association of Chiefs of Police (IACP) resolution calling for government concern and involvement in this area. In sum, the assessment found that even with continuous exposure, no measurements at the aperture of the antennas of all devices tested exceeded the maximum acceptable OSHA exposure levels. In the typical case, where the operator is not directly in front of the antenna and is about 1 m (3 ft) or more away from the aperture, the field strengths either were not measurable, or were substantially less than the maximum exposure levels allowable.

The report prepared by NBS is titled, "Field Strength Measurements of Speed Measuring Radar Units." Copies of the complete report may be obtained from either the Office of Law Enforcement Standards, NIST, or the National Technical Information Service, Springfield, VA 22161, under #PB 81-240 079.

Training

In 1982, NHTSA published and distributed a model basic operator training course in radar speed measurement. (A revised edition was published in 1991.) The overall goal of this training program is to improve the effectiveness of speed enforcement through the proper and efficient use of police traffic radar devices. The specific objectives of the radar course are to develop and/or improve the trainee's ability to:

- o Describe the basic principles of radar speed measurement.
- o Acquire and demonstrate basic skills in testing and operating the specific radar instruments.
- o Identify and describe the major components and functions of the specific radar instrument(s) used by the trainee's agency.
- o Identify and describe the laws, court rulings, regulations, policies and procedures affecting radar speed measurement, and speed enforcement in general.
- o Acquire and demonstrate basic skills in preparing and presenting courtroom testimony relating to radar speed measurement and enforcement.

The radar training course is designed in a modular format to provide maximum flexibility for the user. It is comprised of eight units, each of which has specific performance objectives. The formal classroom training comprises a block of 24 instruction hours. Upon successful completion of a written exam, the trainee must undergo a minimum of 16 instruction hours of supervised field practice. After completing the course of instruction, the trainee must be able to demonstrate operational competence before being certified to take enforcement action based on radar speed evidence. Recertification of all operators should occur not more than 3 years from the date of last certification.

Although this course focuses on enforcement and is intended primarily for the law enforcement officer, we recommend participation in the training program by traffic adjudication personnel, e.g., judges, administrative hearing officers, prosecutors, etc. Persons in these positions routinely decide upon the admissibility and weight of radar speed evidence, the strengths and weaknesses of the instruments, and the capabilities and limitations of the operators. This type of training will provide a good working knowledge of radar speed measurement principles and an understanding of the technical issues as they relate to adjudication.

Testing

NHTSA, with the aid of NIST, assisted the IACP in establishing five testing laboratories at universities in disparate parts of the country. These laboratories are of two different types, Consumer Products List (CPL) and Critical Performance Testing (CPT). The CPL laboratories test new type radar units and provide the IACP with the testing information necessary to produce a Consumer Products List of police radar devices that meet the requirements of these model specifications. The Consumer Products List is updated and published by the IACP on a periodic basis. The CPT laboratories test prescribed number of units which appear on the CPL both immediately following the unit's inclusion on the list and on a periodic basis throughout the unit's manufacturing life. These laboratories are also available to the law enforcement community for recertification testing by contacting the IACP.

Conclusions/Recommendations

NHTSA believes that police traffic radar is an effective enforcement tool. The role of police traffic radar in traffic enforcement continues to be of critical importance. Police traffic radar provides a means of increasing enforcement effectiveness and thus enables police administrators to cope better with speed related vehicular crashes.

Highway safety and law enforcement officials should recognize the fallacy of purchasing radar devices solely on the basis of economy without due regard to their performance capabilities. These officials must also recognize the importance of greatly improved operator training and State-level policy guidance to ensure high quality and more uniform police radar operations throughout a State. Inaction on these issues by State and local highway safety and law enforcement officials may well result in judicial limitations governing the use of police traffic radar.

It is important that each State develop a comprehensive radar speed enforcement program which, as a minimum, embraces model performance specifications for radar purchases, operator training, operator certification, and policy/procedural guidance. Accordingly, each State is strongly urged to:

- Adopt the NHTSA/NIST/IACP model minimum radar speed measuring device performance specifications and require police agencies to purchase devices meeting those specifications.
- Develop policy guidelines to ensure that radar speed measuring devices receive proper care and upkeep and establish clear procedures for programmed maintenance, testing, and calibration.

- Ensure that adequate maintenance and recertification record systems (suitable for introduction as evidence in court) are developed and maintained by each agency using radar speed measuring devices.
- Adopt the NHTSA radar operator training program or its equivalent as the statewide minimum training standard.
- Develop a comprehensive, State-level radar operator certification program and provide for periodic recertification (every 1-3 yrs).
- Develop police radar workshops and seminars for traffic adjudication personnel.
- Establish State-level policy/procedural guidelines to ensure proper use of police traffic radar in meeting highway safety goals and objectives.

Implementation of these measures should result in significantly improved and more uniform radar speed enforcement programs both within the individual States and nationwide. Adoption of these measures is necessary to establish a sound legal foundation for evidence in speeding cases and to maintain public and judicial confidence in radar enforcement programs.

CHAPTER 2
DISCUSSION ABOUT
THE MODEL MINIMUM PERFORMANCE
SPECIFICATIONS

Introduction

After thorough review of comments received in response to the proposed rulemaking for performance standards for radar speed measuring devices, NHTSA decided to terminate the rulemaking process. The benefits of the proposed rule can be achieved without the issuance of a Federal regulation. Therefore, NHTSA released the results of its technical research on radar to the public in the form of the (revised) model minimum performance specifications found in Chapter 3 of this report. The States and local jurisdictions are free to adopt these specifications if they choose.

Background

For almost 40 years, radar has been accepted by the courts and public as a reliable tool for measuring vehicular speed. Its use to enforce traffic laws has saved countless lives by deterring motorists from driving at excessive unsafe speeds. Its continued use and acceptance are vital to improve traffic safety. It is, therefore, essential that radar devices be reliable and accurate.

Until the initial publication of this document, there had been no industry-wide performance standards for police traffic radar devices. State administrators and purchasing agents had no definitive guidelines on which to base their purchasing decisions.

In 1976, after having recognized these limitations, the International Association of Chiefs of Police (IACP) passed a resolution calling for Federal Government concern and involvement in the development of health, safety, and performance standards for speed measuring devices, testing of the devices, and the publication of the results.

In 1977, as a result of the IACP resolution, NHTSA initiated efforts to develop performance standards for speed measuring radar devices to meet the needs of law enforcement. NHTSA called upon the expertise of the Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS) [now the Office of Law Enforcement Standards (OLEs) of the National Institute of Standards and Technology (NIST)] to determine the most desirable and useful features of radar devices. NBS tests formed the basis for the performance standards proposed by the Agency in a notice published in the Federal Register on January 8, 1981 (46 FR 2097).

On January 8, 1981, the performance standards for radar speed measuring devices appeared as a proposed rulemaking in the Federal Register (46 FR 2097).

The most significant objections to the original proposed rule and NHTSA's responses are set forth below for historical and informational purposes:

Minimum Range: The proposed rule contained a provision which would have required each radar device operating in the stationary mode to measure and display the speed of a vehicle correctly at a distance of 500 ft. Several commentors stated that the test was not repeatable because the target description and environmental conditions were not sufficiently specific. Some commentors suggested defining the vehicle in terms of its cross section, while another indicated that the exact make, model, and year of the vehicle should be specified. NHTSA shares the commentors' concerns and has deleted this requirement from the model specifications.

Radar Horizontal Capture Angle. The proposed rule would have required manufacturers to specify the radar horizontal capture angle as measured within the -10 dB points and to scribe or otherwise mark that angle on the top surface or antenna of each radar device. After consideration of this issue, NHTSA has decided that scribing the capture angle onto the antenna would not increase target vehicle identification but could, in fact, mislead the operator in making such identifications by leading him to false conclusions about the beam coverage area. Operators must consider every approaching vehicle as a possible target whose speed could be displayed on the radar device, regardless of its position relative to the radar device. This requires the operator to consider all target vehicles, including those outside the normal parameters of the beam coverage area. The scribing requirement has accordingly been deleted.

In addition to the potential confusion to operators, the requirement of a radar capture angle label would also create several pragmatic problems. Some radar antennas are quite small and have curved surfaces which could distort the operator's perception of the size of the angle. Separately mounted antennas are frequently placed in positions which would prevent the operator from seeing the label while using the equipment, thus also causing a distorted view of the angle or total inability to use it. The Agency agrees with the many individuals and organizations who commented that target identification should be a function of operator training and thus has deleted this requirement from the model specifications.

Antenna Horizontal Beamwidth. Considerable attention has been devoted to the proposed maximum beamwidths of 18° for type I and II (X-Band) and 15° for type III and IV (K-Band) radar devices. Suggestions ranged from unlimited beamwidth for stationary devices to 5° for all devices. NBS conducted extensive tests in order to establish beamwidth values that would result in reliable radar units. The 15° maximum value for K-band (type III and IV)

devices was requested by the Intergovernmental Radio Advisory Commission and established by the Federal Communications Commission (FCC) for State and local government use of these devices. For radar operating in X-band frequencies, the testing showed that 18° maximum width will provide satisfactory performance. Beamwidths in excess of these values become susceptible to environmental interference, thus reducing radar effectiveness. Beamwidths that are too narrow would result in bulkier, larger antennas, and would also make the development of a continuous target tracking history difficult. Therefore, the beamwidths set forth in the model specifications are the same as those in the proposed rule.

Operational Tests. The model specifications suggest that each radar device not be susceptible to erroneous readings from test signals simulating normal exposure to CB and police radios, patrol vehicle ignitions, alternators, air conditioners, and heater fans. Electromagnetic interference tests are established to ensure compliance with these requirements. To further ensure that devices are not prone to spurious radiated energy signals, procedures are established for testing the devices against interference from CB and police radios and adjacent vehicle radios in an actual operating environment. The proposed rule would have also required operational field tests to be conducted for interference from vehicle ignitions, alternators, air conditioners, and heater fans. After thoroughly examining the comments, the Agency feels that these latter requirements are adequately addressed in the laboratory tests and has, therefore, omitted them from the model specifications.

While some commentators suggested deleting all the operational tests because the conditions in a field environment are necessarily more variable than those in a laboratory environment, the Agency believes that the remaining field tests cannot be simulated in the laboratory using existing techniques and that they provide essential data on the performance characteristics of radar devices.

Speed Accuracy. One commentator suggested that the speed accuracy test should be conducted using a fifth wheel instead of a stopwatch. Such a change would provide accurate speed readings for the target and patrol vehicles and eliminate the necessity for a significant number of test runs on a measured course. However, after reviewing the requirements necessary for a fifth wheel, the Agency concluded that the cost of conducting tests using two fifth wheels greatly outweighs the benefits to be gained, and has therefore decided to retain the stopwatch provisions.

Auto Lock. The elimination of the automatic self-lock capability represents one of the most significant features of the model specifications. The inclusion of the automatic lock would have

allowed the radar device to lock automatically onto any vehicle traveling faster than a preset threshold speed, thus making it harder for the operator to identify the target being tracked. The auto lock feature also allows the radar unit to lock onto a spurious signal in the absence of a bona fide target vehicle. By using a radar device without this feature, a skilled and knowledgeable operator can develop a vehicle's tracking history and thereby avoid virtually all of the alleged anomalous readings ascribed to radar operation. The elimination of this feature is consistent with the NHTSA training program which emphasizes that the tracking history is an essential part of radar operation, ensuring proper target vehicle identification.

Audio Alarm. The model specifications suggest omission of audio alarm features which emit an audio signal to alert the operator when a specific speed threshold has been exceeded by a target vehicle. Like the automatic self-lock, the inclusion of this feature can tempt the operator to be careless in his or her efforts to obtain a proper target history, relying instead on the alarm. In addition, it sometimes disrupts the audio tracking capability of the operator.

Doppler Audio. The model specifications suggest that all devices be equipped with a doppler audio feature which correlates the speed of the target vehicle with the sound emitted by the radar device. This feature also warns the operator when there is an excessive amount of electromagnetic interference, present, thereby making use of the equipment inappropriate for tracking vehicle speeds. It also helps the operator determine when traffic is too dense to identify individual targets. The Agency regards this feature as highly desirable in obtaining a proper tracking history.

Patrol Speed Window--Moving Radar. Some commentators objected to the inclusion of a window to display patrol speed on moving radar on the grounds that the patrol speed could be read directly from the speedometer. It is the opinion of NHTSA that all moving radar operation should be conducted with devices that have a patrol speed window which allows the operator to compare the speed displayed on the radar devices with that registered on the vehicle speedometer. This is the best way to properly identify and counter some of the erroneous readings that can be attributed to moving radar operation.

Test Equipment. Specific suggestions were received from one commentator regarding the selection of some of the equipment to be used in the conduct of laboratory procedures for testing. Of specific importance were the comments received with respect to the single-side-band modulator, the pulse generator, and the AM signal generator.

After careful consideration of the suggestions and review of the NBS testing, we have decided to retain the equipment specified in the proposed rule for the following reasons:

- o Single-side-band modulator (SSB). It was suggested that a double-side-band modulator be used in lieu of the SSB because it is less expensive and produces more accurate results. NBS test experience shows that the SSB provides a clearer signal, generates less noise, and provides more accurate and repeatable results. While the SSB is more expensive (an increase of approximately 50 percent), this amount is not excessive when compared to the benefits to be gained.
- o Pulse generator. It was suggested that the required 20 volt peak-to-peak (20 V p-p) pulse generator is not necessary and that a 10 V p-p generator would be sufficient. However, the signal generated using an output of 10 V p-p did not accurately depict the interference found in the engine compartment of a typical police vehicle. Thus, it was decided a 20 V p-p signal must be used.
- o AM signal generator. Another commentor expressed his opinion that the AM signal generator in the proposed rule was over-specified, suggesting that the 99 percent modulation should be reduced to 90 percent. A survey of CB radios shows that there are a significant number that exceed the 40 to 70 percent modulation range. Therefore, it is our belief that the higher modulation is essential in order to include the widest range CB radios in the marketplace.

Manufacturer Provided Information. A number of comments were received concerning the adequacy of manufacturer provided information. Only minor changes have been made in that section of the model specifications. Manufacturers are strongly encouraged to provide thorough instructions for the proper installation and use of their devices. These instructions will be used in conducting operational tests. Inadequate instructions may reduce the clarity of procedures that will be used when testing the devices in the field. Questions concerning the adequacy of an agency's operating procedures can be virtually eliminated by showing the courts and the public that radar operators received proper training and instructions in the installation and use of radar devices.

As a final note to those commentors who expressed concern that a reference to conformity with FCC regulations does not appear in the proposed rule, NHTSA wants to emphasize that the issuance of these model minimum specifications does not conflict with any requirements established by the FCC or any other regulatory body.

All applicable regulations must be complied with. It is the responsibility of each manufacturer to be aware of those requirements that must be met. NHTSA will assist those manufacturers who need guidance in this area, but does not consider these model specifications to be the appropriate place to cite those requirements.

On November 19, 1981, following an extensive review and comment period, NHTSA made a decision to issue a notice terminating the rulemaking action and published the revised standards in March 1982 as Model Performance Specifications for Police Traffic Radar Devices (DOT-HS-806-191). The IACP subsequently adopted these specifications, at the recommendation of the Technology Assessment Program Advisory Council, as an IACP specification document for radar devices.

During the period following the issuance of the proposed rulemaking, the manufacturers of radar devices continued to make modifications to their products directed toward complying with or exceeding the requirements of the model specifications. Publication of the model specifications prompted the IACP to submit a proposal to test radar speed measuring devices to determine compliance with the model specifications and to prepare a consumer products list in the same manner as other types of equipment being tested by the IACP. The unsolicited proposal was accepted by NHTSA and in October 1982, the IACP entered into an agreement to accomplish the testing of radar devices and publish the test results.

The radar manufacturers voluntarily submitted their products to the testing laboratories. The final testing was completed and the reports were received by the IACP on January 16, 1984. The two volume test reports were published in April 1984.

In May 1989, NHTSA published a revision to the Model Minimum Performance Specification for Police Traffic Radar Devices (DOT HS 807-415) which included multi-directional radar units.

The specifications set forth in this document represent those attributes and features of speed measuring devices considered most desirable by a wide consensus of radar users, manufacturers, and the courts. They are not intended to preclude or inhibit the development or introduction of new technology in the speed measuring device industry. As such advancements are made, the Agency will incorporate them into the existing model specifications. A number of minor changes and clarifications have been incorporated into this edition of the model minimum specifications as a result of suggestions made by users and manufacturers and as dictated by changing technology.

To complement these specifications, NHTSA has also developed and widely distributed a model operator's training course for users

of police traffic radar. When adopted by State and local jurisdictions, this model training course should upgrade the quality of radar training that most police officers receive. The training program, coupled with the performance specifications, should ensure the continued reliability and accuracy of radar devices.

The responsibility for oversight of the IACP testing program was and continues to be assigned to its Highway Safety Advisory Committee. This standing committee appointed a technical advisory committee on radar which is, in part, comprised of the radar manufacturers, a member from OLES and a member from NHTSA. These revised Model Minimum Specifications for Police Traffic Radar Devices are a product of these committees, and incorporate changes to the specifications required by constantly improving technology.

The Agency still intends to be responsive to the 1976 resolution regarding police traffic radar issued by the IACP. Therefore, we have authorized the IACP to adopt these model specifications for radar devices. We expect them to provide their constituents with the best available guidance on police traffic radar devices. The results of this work should fortify their efforts to assist the police in retaining these devices as effective law enforcement tools, while allowing NHTSA to meet its obligations to provide technical assistance to the traffic law enforcement community. The IACP's efforts will involve both (1) oversight of the research/testing program, in collaboration with NIST and NHTSA, and (2) publication/dissemination of the results of the testing of all interested parties.

NHTSA still believes a research/testing program is an integral part of the assessment of radar devices. The purpose of this testing program is to provide the IACP and law enforcement with definitive test data on how the radar devices on the market perform when compared to the model specifications.

CHAPTER 3
MODEL MINIMUM PERFORMANCE
SPECIFICATIONS
FOR POLICE TRAFFIC RADAR
DEVICES

MODEL MINIMUM PERFORMANCE SPECIFICATIONS
FOR SPEED MEASURING RADAR DEVICES

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Table 1 - Minimum performance requirements for speed measuring radar devices

Subpart A - General

§1221.1 Scope

This part establishes performance requirements and test methods for speed measuring radar devices used by law enforcement agencies to enforce vehicle speed regulations.

§1221.2 Purpose

The purpose of this part is to specify performance standards for radar devices.

§1221.3 Application

This part applies to speed measuring radar devices that transmit microwave energy, monitor the reflected signal from moving vehicles within the microwave beam, process the Doppler shift of the reflected signal to display the speed of the vehicle that is being tracked, and if appropriate, the speed of the patrol vehicle. It does not apply to unmanned speed measuring radar devices that are mounted at a fixed angle to the roadway and utilize circuitry to compensate for the reduction in displayed speed due to the cosine effect, nor does it apply to stationary mode radar devices that take photos of vehicles being tracked.

§1221.4 Definitions

As used in this part:

"Accuracy" when used in conjunction with radar devices means the degree to which the radar device measures and displays the correct speed of a target vehicle that it is tracking.

"Ambient interference" means the conducted and/or radiated electromagnetic interference and/or mechanical motion interference, at a specific test location and time, which is detrimental to proper radar performance.

"Antenna horizontal beamwidth" means the total included acute angle, in the horizontal plane, of the main lobe between the half-power points of the radar antenna far-field radiation pattern, where the half-power points are measured relative to the maximum power at the center of the beam and on a radius equidistant from the face of the antenna.

"Automatic lock" means a control function of a radar device that, when activated, causes the device to retain automatically the displayed speed of a target vehicle when the target vehicle speed exceeds some preset value, and preserve that displayed speed until manually reset by the operator.

"Closing speed" means the speed at which an identified radar target is moving relative to the radar device (whether the radar device is moving or not) when measured on a straight line (radius) from the radar to the target.

"Cosine effect" means the effect due to the target not traveling directly toward the radar device. This effect lowers the Doppler shift frequency in proportion to the cosine of the angle between the direction of travel of the radar target and a line from the radar device to the target.

"Display" means a visual readout device.

"Doppler audio" means an audible signal from a radar device that is generated by driving a loudspeaker with the Doppler shift beat frequency or with the Doppler shift beat frequency divided by a fixed factor, provided the audio sound corresponds directly to changes in speed of target vehicle, and any ambient interference present is discernible.

"Doppler shift" means the magnitude of the frequency change of the radar return signal received when the source and the radar reflecting target are in motion relative to one another.

"Erroneous reading" means an incorrect target speed displayed by the radar device, one that is not due to a target vehicle or which is not within the required accuracy tolerance of the speed of a target vehicle, excluding known correction factors such as the cosine effect.

"Far-field region" means that region beyond the close proximity of a transmitting antenna defined by the relationship

$$R > \frac{2d^2}{\lambda}$$

where d is the horn diameter and λ is the wavelength of the transmitted frequency, in consistent units.

"Internal circuit test" means a test function (whether manually or automatically initiated) that verifies that all radar device internal signal-processing circuitry, except for the microwave transmitter and receiver, is working correctly, i.e., all target and patrol vehicle signals will be properly processed and displayed.

"Just acquired distant target" means a target just within the radar range of a radar device which was originally beyond the range and now provides a display signal of target speed.

"K-Band radar" means a speed measuring radar device designed to operate in the 24 050 to 24 250 MHz frequency band.

"Ka-Band radar" means a speed measuring radar device designed to operate in the 33 400 to 36 000 MHz frequency band.

"Low voltage indicator" means a radar device component which alerts the operator to the fact that a low supply voltage condition exists.

"Luminance" means the photometric brightness or the luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction.

"Luminance contrast" means the relationship between the luminance of an object and the luminance of its own background.

"Microwave output power" means that part of the total power produced by the microwave generator in the radar devices.

"Moving mode" means the capability of a radar device to measure and display the speed of a target vehicle while the radar device is moving with respect to the surrounding terrain.

"Near-field region" means that region in close proximity to the transmitting antenna that is not included in the region defined as "far-field region."

"Nominal value" means the numerical value of a device characteristic as specified by the manufacturer.

"Opposite direction moving mode" means that a radar device has the ability to measure and display the speed of a target vehicle while the radar device and the target vehicle are moving in opposite directions.

"Patrol channel" means that portion of the radar circuitry of a radar device that processes and calculates the speed of a patrol vehicle when the radar device is operating in the moving mode.

"Patrol speed" means the speed at which the patrol vehicle is moving with respect to the surrounding terrain.

"Polarization" means that property of a radiated electromagnetic wave describing the time-varying direction and magnitude of the electric field vector.

"Power density" means power density per unit area or energy density flux per unit area.

"Same direction moving mode" means that a radar device has the ability to measure and display the speed of a target vehicle while the radar device and the target vehicle are moving in the same direction.

"Side lobes" means radar beams from the antenna which are not part of the primary beam, but which may appear as shoulders on the primary beam.

"Speed display transfer" means the capability of transferring the speed reading from the patrol speed display window to the target speed display window.

"Speed lock switch" means a radar control that causes speed on display as target speed and patrol speed to be retained on display until reset.

"Speed monitor alert" means a function that alerts the operator when a target speed signal is received that is equal to or above some preselected threshold speed.

"Squelch" means the capacity of a radar to inhibit the Doppler audio sound when the radar is in operation and not receiving a target signal.

"Standby mode" means the state of a radar device in which power to the microwave oscillator is inhibited, preventing the device from transmitting an rf signal, although all remaining circuitry is normally powered and functioning.

"Stationary mode" means the capability of a radar device to measure and display from a fixed location the speed of a target vehicle.

"Target channel" means the portion of the radar circuitry that processes the closing speed signal, and calculates and displays the speed of a radar target.

"Target speed" means the speed at which the target vehicle is moving with respect to the surrounding terrain.

"Target vehicle" means the vehicle identified as producing a given Doppler radar signal that is processed and displayed by the radar device as the target speed.

"Track-through-lock" means the feature of a radar device whereby the unit continues to measure, process and accomplish Doppler audio tracking and, in some cases, display in real time the target speed after the speed lock switch has been actuated to the lock condition.

"Tuning fork" means a mechanical self-resonant device, which when excited, produces free oscillations that may be used to generate a pseudo Doppler frequency reference when placed in the radar antenna beam.

"Type I radar device" means a radar device that transmits microwave energy in the 10 500 to 10 550 MHz frequency band (in the X-band) and operates only in the stationary mode.

"Type II radar device" means a radar device that transmits microwave energy in the 10 500 to 10 550 MHz frequency band (in the X-band) and operates in both the stationary and moving modes.

"Type III radar device" means a radar device that transmits microwave energy in the 24 050 to 24 250 MHz frequency band (in the K band) and operates only in the stationary mode.

"Type IV radar device" means a radar device that transmits microwave energy in the 24 050 to 24 250 MHz frequency band (in the K-band) and operates in both the stationary and moving modes.

"Type V radar device" means a radar device that transmits microwave energy in the 33 400 to 36 000 MHz frequency band (in the Ka-band) and operates only in the stationary mode.

Type VI radar device" means a radar device that transmits microwave energy in the 33 400 to 36 000 MHz frequency band (in the Ka-band) and operates in both the stationary and moving modes.

"X-band radar" means a speed measuring radar device designed to operate in the frequency band of 10 500 to 10 550 MHz.

Subpart B - Requirements

§1221.11 Manufacturer Provided Equipment

Each type I, III, and V radar device shall be accompanied by a minimum of one tuning fork and each type II, IV, and VI radar device shall be accompanied by a minimum of two tuning forks.

§1221.12 Manufacturer Provided Information

(a) Each radar device submitted for testing in accordance with the provisions of these specifications shall be accompanied by the following minimum information:

(1) Complete instructions for installing the radar in or on the police patrol vehicle or remote from the vehicle including any precautions necessary to minimize or avoid interference from vehicle ignition, heater/air conditioner/defroster blowers or other potentially interfering components.

(2) Complete operating instructions including test procedures, internal circuit test data, required maintenance, and any operating characteristics that are indicative of or symptomatic of possible malfunction of the radar.

(3) Nominal power supply voltage and currents (with and without displays illuminated; with and without target present, and in standby mode if appropriate).

(4) The microwave frequency band of operation.

(5) The nominal value of microwave output power (in milliwatts) as measured by a microwave power meter connected to the microwave oscillator.

(6) Lowest and highest supply voltage level at which the radar is designed to operate, the low voltage alert threshold value and display behavior.

(7) Maximum microwave power density (mW/cm^2) measured in a plane 5 cm (2 in) distant from the front of the antenna.

(8) Antenna horizontal beamwidth in degrees.

(9) Type of antenna polarization, i.e., linear or circular and orientation.

(10) Minimum and maximum operating speed of the radar device [target (types I, III, and V); target and patrol (types II, IV, and VI)].

(11) The highest and lowest temperature at which the unit is designed to operate.

(12) The highest temperature and humidity combination at which the radar device is designed to operate.

(b) Each tuning fork shall be accompanied by a calibration certificate including as a minimum the serial number of the

tuning fork, the nominal design speed, a frequency calibration at 21°C (70°F), the microwave frequency band for which it is to be used (X, K, or Ka), the calibrated frequency and associated radar speed in mph or km/h, and any correction factor that must be applied to the 21°C (70°F) calibration speed when used at another temperature.

§1221.13 Labeling Requirements

(a) Tuning Fork. The manufacturer shall permanently mark each tuning fork with a serial number, the radar frequency band that is to be used with (X, K, or Ka), and a nominal stationary model radar speed specification including units (km/h or mph). Each Ka band tuning fork shall also be permanently marked with the nominal microwave frequency of its radar device, or marked with a code representing the same.

(b) Control Functions. The control panel of the radar device shall be permanently marked with the functions and settings of all switches, controls, and displays. It shall not be possible to set the controls to a functional mode of operation that is not marked or identified on the control panel of the radar device.

§1221.14 Tuning Fork Calibration Requirement

When tested in accordance with §1221.71, the frequency of vibration of each tuning fork shall be within $\pm 1/2$ percent of that specified by the manufacturer (§1221.12(b)) in the certificate of calibration for that tuning fork.

§1221.15 Radar Device Tuning Fork Requirement

Each radar device when tested in accordance with §1221.72 shall meet the following tuning fork requirements, as appropriate.

(a) All Radar Devices. Each radar device, when placed in the stationary mode, shall respond to the signal from the tuning fork within ± 2 km/h (± 1 mph) of the speed corresponding to the tuning fork frequency.

(b) Type II, Type IV, and Type VI Radar Devices (Opposite Direction Moving Mode). Each type II, IV, and VI radar device, when placed into the opposite direction, moving mode, shall simultaneously respond to the signals from two vibrating tuning forks of different frequencies, and shall display the calibration speed designated for the lower frequency tuning fork as the patrol vehicle speed, and the difference between the calibration speed designated for the higher frequency tuning fork and that of the lower frequency tuning fork as the target vehicle speed; both displayed speeds shall be within ± 2 km/h (± 1 mph) of the correct values.

(c) Type II, Type IV, and Type VI Radar Devices (Same Direction Moving Mode). Each type II, IV, and VI radar device, when placed into the same direction, moving mode (if such capability is provided by the unit) shall respond to the signals from two simultaneously vibrating tuning forks of different frequencies, and shall display the calibration speed designated for the higher frequency tuning fork as the patrol vehicle speed, and the sum of the calibration speed designated for the higher frequency tuning fork and that of the lower frequency tuning fork as the target vehicle speed; both displayed speeds shall be within ± 2 km/h (± 1 mph) of the correct values.

§1221.16 Microwave Transmission Requirements

The microwave characteristics of transmission frequency and frequency stability, input current stability, radiated output power stability, antenna horizontal beamwidth, and antenna near-field power density shall be measured in accordance with §1221.73 and shall meet the following requirements:

(a) Transmission Frequency and Frequency Stability. When operated at the standard supply voltage (cf §1221.31(c)), the transmission frequency shall be within the assigned frequency band of 10 500 to 10 550 MHz for types I and II radar devices, 24 050 to 24 250 MHz for types III and IV radar devices, and 33 400 to 36 000 MHz for type V and VI radar devices. When the input voltage is raised to 20 percent above the nominal supply voltage, or to the manufacturer's specifications if higher, or lowered to 20 percent below the nominal supply voltage [8 percent for nickel cadmium (NiCd) battery pack] or to the manufacturer's low voltage value (whichever is lower) the transmission frequency shall remain within the assigned frequency band. In addition, for a type V or VI radar device the frequency shall remain within ± 100 MHz of its nominal value.

A radar device powered by a NiCd battery pack and designed to also use a nominal 12 V automotive battery and adapter as an optional source of power shall also be tested for transmission frequency and frequency stability utilizing this adapter and a standard supply voltage of 13.6 V ± 20 percent.

(b) Input Current Stability. When the standard supply voltage is varied ± 20 percent (-8 percent for NiCd battery pack), the input current shall not vary more than 25 percent from its nominal value, with no variation in the numerical figure displayed on the target speed display.

(c) Radiated Output Power Stability. The microwave carrier output power shall not vary by more than ± 1.5 dB from the nominal value when the standard supply voltage is varied ± 20 percent (-8 percent for NiCd battery pack).

(d) Antenna Horizontal Beamwidth. The total included angle between the -3 dB power points of the main lobe of the microwave beam, relative to the maximum power at the center of the beam,

shall not exceed 18° for type I and II and 15° for type III, IV, V, and VI radar devices.

(e) Antenna Near-Field Power Density. The maximum antenna near-field power density of each radar device shall not exceed 5 mW/cm² (§1221.12(a)(7)). A radar device powered by a NiCd power pack, and designed to use a nominal 12 V automotive battery and adapter as an optional source of power, shall also be tested for near-field power density utilizing this adapter.

In addition, the manufacturer of each hand-held radar device shall make available to purchasers the following optional feature:

(f) Standby/Operate Switch. A positive action control ("standby/operate switch") which, when used in a stationary mode, must be held depressed for the radar to transmit rf electromagnetic energy. When this control is released the hand-held radar device shall cease to transmit electromagnetic energy, i.e., return to the rf standby mode. When a unit is equipped with this option, no mechanism shall exist, as a part of the radar device, to lock this control switch in the transmit position. The operation of the standby switch shall be verified in accordance with §1221.73(f).

§1221.17 Environmental Requirements

The ability of the radar device to operate in environmental extremes shall be determined using the appropriate test methods described in §1221.74 and each radar device shall meet the following requirements:

(a) Operational Temperature Stability. When tested in accordance with §1221.74(a), following exposure to a temperature of -30°C (-22°F) or the lowest temperature at which the manufacturer states that the radar devices will operate properly (§1221.12(a)(11)), whichever is lower, and following exposure to a temperature of 60°C (140°F) or the highest temperature at which the manufacturer states that the device will operate properly (§1221.12(a)(11)), whichever is higher, each radar device shall continue to meet the requirements of §1221.15 and §1221.16 through §1221.16(c).

(b) Operational Humidity Stability. When tested in accordance with §1221.74(b) following exposure to 90 percent relative humidity at 37°C (99°F) for a minimum of 8 h, each radar device shall continue to meet the requirements of §1221.15 and §1221.16(a) through §1221.16(c).

(c) Vibration Stability. No fixed part of the radar device shall come loose, nor movable part be shifted in position or adjustment, as a result of the test conducted in accordance with

§1221.74(c). During the last 5 minutes of the test in any one direction, the radar device shall respond to the tuning fork signal and shall display the designated tuning fork speed within ± 3 km/h (± 2 mph).

§1221.18 Low Supply Voltage Requirement

Each radar device shall have a low voltage indicator capable of being seen and/or heard by the operator. When tested in accordance with §1221.75, the low voltage indicator shall activate if the supply voltage is reduced to 10.8 V or the lowest voltage at which the radar device is designed to operate, whichever is lower. For devices utilizing a NiCd battery pack, the low voltage indicator shall operate at 92 ± 3 percent of the standard supply voltage defined in §1221.31(c) or the lowest voltage specified by the manufacturer, whichever is lower. When the supply voltage is reduced to the low voltage alarm value, the radar shall not display any erroneous readings when subjected to the tuning fork test (§1221.72). A blank display is not considered an erroneous reading.

§1221.19 Doppler Audio Requirements

The Doppler audio output characteristics of audio output and volume control, audio squelch and squelch override, audio track-through-lock, and speed monitor alert shall be tested in accordance with §1221.76 and each radar device shall meet the following requirements:

(a) Audio Output and Volume Control. The radar device shall emit a Doppler audio tone that is correlated with the received Doppler signal and any interference present, and it shall have an audio volume adjustment control.

(b) Audio Squelch and Squelch Override. When the radar device is operated, the Doppler audio tone shall be squelched as long as no target speed signal is being processed. When a target speed signal is present, the Doppler audio signal shall be present in the audio output. The radar device shall permit the operator to inhibit the squelch action to keep the receiver open.

(c) Audio Track-Through-Lock. For those radar devices with a track-through-lock feature, the Doppler audio tone shall continue to follow the received Doppler signal when the speed lock switch is activated.

(d) Speed Monitor Alert. The radar device shall not have a speed monitoring alert capability.

§1221.20 Power Surge Requirements

The power surge characteristics exhibited when switching the radar device from standby to on shall be tested in accordance with §1221.78. Switching the radar device from standby to on shall not cause any erroneous speed readings with a target present.

§1221.21 Speed Display Requirements

The speed display characteristics of display readability, display speed lock control, display clear function, internal circuit test function, speed display transfer, signal processing channel sensitivity, target channel speed displays, patrol channel speed displays, and auxiliary displays shall be tested in accordance with §1221.79 and shall meet the following requirements:

(a) Display Readability. The illuminated segments used to indicate speed readings shall have a minimum daylight luminance contrast of 2.5 when compared with the display background.

(b) Display Speed Lock Control. If provided, the speed lock switch shall preserve the displayed target vehicle and patrol vehicle (types II, IV, and VI) speed readings. The speed lock switch shall require manual actuation by the radar operator and shall not be capable of automatic self-lock. When the radar device has a track-through-lock capability, the speed reading(s) displayed after locking shall be the target speed and patrol speed (types II, IV, and VI only) that existed at the instant the speed lock switch was activated. The radar device shall not recall a previous speed reading when the speed lock switch is activated. The radar device shall not be capable of blanking the patrol speed display except after it is locked.

(c) Display Clear Function. The selection of a different mode of operation of the radar device such as switching from off to on, lock to clear, between stationary and moving mode, opposite and same direction mode, or faster and slower target mode, shall automatically clear the radar device of all displayed readings whether the speed lock switch is activated or not, unless the radar device retains displayed information indicating the mode used to acquire the locked-in target speed. It shall be permissible to accomplish a test sequence without clearing locked-in speed readings.

(d) Internal Circuit Test Function. The radar device shall have a self-test function that, when activated, determines whether or not internal signals will be processed and displayed to within ± 2 km/h (± 1 mph). The radar device shall display the correct reading(s) when performing the internal circuit test function and it shall be impossible for the radar device to lock in the speed displays caused by this test. These readings shall be cleared when the radar is switched to another mode of

operation. The internal circuit test switch shall not be labeled "Cal" or "Calibrate."

(e) Speed Display Transfer. In the moving mode the radar device shall not be capable of transferring the patrol speed reading from the patrol speed display to the target speed display.

(f) Signal Processing Channel Sensitivity.

(1) Stationary Mode Target Channel Sensitivity. When the radar device is operated in the stationary mode, its signal processing channel sensitivity shall not vary more than 10 dB for targets traveling at speeds of 56 to 144 km/h (35 to 90 mph) nor more than 5 dB for targets traveling at speeds of 96 to 144 km/h (60 to 90 mph).

(2) Opposite Direction Moving Mode Target Channel Sensitivity (Types II, IV, and VI Only). When the radar device is operated in the opposite direction moving mode at a patrol speed of 40 km/h (25 mph), its closing-speed channel sensitivity shall not vary more than 10 dB for targets traveling at speeds of 64 to 144 km/h (40 to 90 mph), except for those targets traveling at the patrol speed or a multiple of the patrol speed. When operated at a patrol speed of 80 km/h (50 mph), its closing-speed channel sensitivity shall not vary more than 5 dB for targets traveling at speeds of 96 to 144 km/h (60 to 90 mph).

(3) Same Direction Moving Mode Target Channel Sensitivity (Types II, IV, and VI Only). When the radar device is operated in the same direction moving mode at either 88 or 64 km/h (55 or 40 mph), its signal processing channel sensitivity shall not vary more than 10 dB for targets traveling within 8 to 40 km/h (5 to 25 mph), faster, or slower, of the patrol speed.

(g) Target Channel Low and High Speed Displays.

(1) The target signal processor channel and target speed display shall function as specified in the test procedure in §1221.79(g) at a speed of 32 km/h (20 mph) or the lowest speed at which the manufacturer states that his device will operate properly, whichever is lower, when operating in the stationary or moving mode.

(2) The target signal processor channel and target speed display shall function as specified in the test procedure at §1221.79(g) at a speed of 160 km/h (100 mph) when operating in the stationary mode. While operating in the moving mode, type II, IV, and VI radar devices shall process closing speeds of at least 272 km/h (170 mph) but type IV radars shall not process closing speeds of 336 km/h (210 mph) or greater.

(h) Patrol Channel Speed Displays (Types II, IV, and VI Radar Devices).

(1) Low and High Speed Readings:

(i) The patrol signal processor channel and patrol speed display shall function as specified in the test procedure at §1221.79(h)(1), at speeds down to 32 km/h (20 mph) or the lowest speed at which the manufacturer states that the unit will operate properly (§1221.12(a)(10)), whichever is lower, when operating in the moving mode.

(ii) The patrol signal processor channel and the patrol speed display shall function as specified in the test procedure at §1221.79(h)(1) at a speed of 112 km/h (70 mph) or the highest speed at which the manufacturer states that his unit will operate properly (§1221.12(a)(10)), whichever is higher, when operating in the moving mode.

(2) Patrol Vehicle Speed Changes. When tested in accordance with §1221.79(h)(2) the patrol signal processor channel shall track the patrol car speed within ± 2 km/h (± 1 mph) and maintain proper radar performance while the patrol car changes speed at a rate of 4.8 km/h (3 mph) per second.

(i) Auxiliary Displays. If the radar device has auxiliary speed displays, the requirements specified for the target channel and patrol channel displays shall apply to the auxiliary displays.

(1) If the radar device utilizes a printing device to record permanently the speed display readings, this printed record shall show the operating status (stationary or moving mode), the retained patrol vehicle and target vehicle speeds and the time of day and date at which the speed lock switch is activated.

(2) If the radar device utilizes a separable, remote module, this remote module shall display, as a minimum, the retained target vehicle speed. The remote module shall clear all displays when reconnected to the radar device or when a display clear function occurs.

(j) Same Direction Moving Mode Speed Computation Indicator (Types II, IV, and VI Only). For those radar devices having a same direction moving mode capability, the readout unit shall have a visual indicator designating whether target speed is being computed on the basis of a target vehicle traveling faster or slower than the patrol vehicle.

§1221.22 Electromagnetic Interference Susceptibility
Requirements

The susceptibility of the radar device to simulated electromagnetic interference from the vehicle alternator, vehicle

ignition, air conditioner/heater motor, windshield wiper motor, and typical police and citizens band transceivers shall be tested in accordance with §1221.80. A radar device powered by a NiCd battery pack and also designed to use a nominal 12 V automotive battery and adapter as an optional source of power shall also be tested for susceptibility to electromagnetic interference (a, b, c, and d) utilizing this adapter. During these tests, a blank target speed display shall not be considered an erroneous reading. Each radar device, when tested in accordance with §1221.80, shall meet the following requirements:

(a) Simulated Vehicle Alternator Interference. When subjected to a 10-20 μ s wide pulse signal of 1 V p-p amplitude (except for transition spikes) having a maximum rise time of 2 μ s and a maximum fall time of 2 μ s (both excluding ringing) and having a ringing time no greater than 8 μ s, with a pulse repetition rate between 200 and 10 000 pulses per second (pps), the radar device shall not display any erroneous readings.

(b) Simulated Vehicle Ignition, Air Conditioner/Heater Motor and Windshield Wiper Motor Interference. When subjected to a negative ramp sawtooth wave signal of 1 V p-p with a positive rise time of a maximum of 2 μ s over a frequency range of 200 to 10 000 Hz, the radar device shall not display any erroneous readings.

(c) Simulated Police FM Transceiver Interference. When subjected to a 10 mW frequency modulated (FM) radio frequency signal in each police radio frequency band, the radar device shall not display any erroneous speed readings.

(d) Simulated Citizen Band (CB) AM Transceiver Interference. When subjected to a 5 mW amplitude modulated (AM) radio frequency in any of the CB channels specified in §1221.80(d), the radar device shall not display any erroneous speed readings.

§1221.23 Radar Device Operational Test Requirements

The operational test requirements of radio frequency transceiver interference and speed accuracy shall be tested in accordance with §1221.81. A radar device powered by a NiCd battery pack, and also designed to use a nominal 12 V automotive battery and adapter as an optional source of power, shall also be tested for operability under requirement (a) for police FM transceiver interference utilizing this adapter. During these tests, a blank target speed display shall not be considered an erroneous reading. Each radar device shall meet the following requirements:

(a) Police FM Transceiver Interference. The radar device shall not display any erroneous speed readings when a police FM

radio transceiver, properly installed in the radar-equipped patrol vehicle, is operated while the patrol vehicle is standing still with the radar device in the stationary mode and tracking a just-acquired distant target traveling at a speed of 80 km/h (50 mph). The radar device shall not display any erroneous readings when a handheld police FM transceiver with an integral antenna is operated inside the patrol vehicle under similar circumstances.

(b) Citizens Band (CB) AM Transceiver Interference. The radar device shall not display any erroneous speed readings when a CB AM transceiver properly installed in the radar equipped patrol vehicle is operated while the patrol vehicle is standing still with the radar device in the stationary mode and tracking a just-acquired distant target traveling at a speed of 80 km/h (50 mph).

(c) Adjacent Vehicle Radiofrequency Interference.

(1) The radar device shall not display any erroneous speed readings when a second vehicle with an operating police FM transceiver is driven within 3 m (10 ft) of the stationary patrol vehicle while the radar device is operating and tracking a just-acquired distant target traveling at a speed of 80 km/h (50 mph).

(2) The radar device shall not display any erroneous speed readings when a second vehicle with an operating CB AM transceiver is driven within 3 m (10 ft) of the stationary radar patrol vehicle while the radar device is operating and tracking a just-acquired distant target traveling at a speed of 80 km/h (50 mph).

§1221.24 Speed Accuracy

When tested in accordance with §1221.82, each radar device shall display the correct speed of a target vehicle traveling at speeds of 32 to 160 km/h (20 to 100 mph) within ± 2 , -3 km/h (± 1 , -2 mph) when operated in the stationary mode. Type II, IV, and VI radar devices shall display the correct patrol vehicle speed and target vehicle speed of a radar target within ± 3 km/h (± 2 mph) when operated in the moving mode.

Subpart C - Test Procedures

CONDITIONS

§1221.31 Conditions

Allow all measurement equipment to warm up until the system has achieved sufficient stability to perform the measurement.

Unless otherwise specified, perform all measurements under standard test conditions as follows:

(a) Standard Temperature. Standard ambient temperature shall be between 20°C (68°F) and 30°C (86°F).

(b) Standard Relative Humidity. Standard relative humidity shall be between 10 and 85 percent.

(c) Standard Supply Voltage. For a nominal 12 V dc automotive system, the standard supply voltage shall be 13.6±0.1 V. In the case of a NiCd battery power supply, the standard supply voltage shall be 1.2 V (nominal voltage under load at half discharge time) multiplied by the number of cells in the battery pack. The standard supply voltage characteristics of other types of battery supplies will be defined as needed. A well-filtered electronic power supply capable of a voltage adjustment of ±25 percent from the nominal should be used for laboratory testing and is recommended for other tests in place of the battery for safety and convenience. The standard supply voltage shall be applied to the input terminals of the dc supply cables (including all connectors and circuit protectors) as furnished by the manufacturer. For a NiCd battery powered device, remove the battery pack and connect the standard supply directly to the radar's battery contacts. In either case adjust the standard supply to within 1 percent of its specified voltage.

(d) Standard supply input current. The standard input current shall be the value measured while the radar is operating and receiving a target signal.

(e) Special instructions. Each time a test method requires that the radar device be connected to the simulator test range (hereafter called "simulator"), the radar device must also be connected to the standard supply voltage source and properly aligned on the simulator.

EQUIPMENT

§1221.41 Equipment

The test equipment discussed in this section is limited to that equipment which is most critical in making the measurements discussed in this document. All other test equipment shall be of laboratory instrumentation quality. All test equipment, except the anechoic chamber, shall be provided with instruction manuals.

§1221.42 Audiofrequency Synthesizer

The audiofrequency synthesizer, usually used for calibrating the tuning forks, shall have a frequency range of 300 to

10 000 Hz, a resolution of at least 0.01 Hz, and a measurement uncertainty no greater than 1 part in 10^6 . If this unit is also to be used in the simulator test range set-up then the upper frequency must be at least 16 kHz.

§1221.43 Microphone

The microphone shall have a frequency range of 300 to 10 000 Hz and shall be capable of coupling tuning fork tones into an amplifier or oscilloscope.

§1221.44 Environmental Chamber

The environmental chamber or chambers shall produce air temperatures that meet the requirements of §1221.17(a) and §1221.17(b) while shielding the test radar device from heating or cooling air currents blowing directly on it. The temperature of the radar device shall be measured with a thermocouple (§1221.61) separate from the sensor used to control the chamber air temperature and shall have an uncertainty no greater than $\pm 1^\circ\text{C}$ ($\pm 2^\circ\text{F}$). Likewise, humidity shall be measured with a hygrometer separate from the sensor used to control humidity and shall have an uncertainty no greater than ± 2 percent.

§1221.45 Anechoic Chamber

The rf anechoic chamber shall be shielded to exclude outside interference and shall be constructed to minimize internal microwave reflections from the chamber wall, floor and ceiling.

§1221.46 Microwave Frequency Counter

The microwave frequency counter shall be capable of measuring microwave frequencies from 10 500 to 10 550 MHz, from 24 050 to 24 250 MHz, and from 33 400 to 36 000 MHz with an uncertainty no greater than 1 part in 10^7 .

§1221.47 Field Strength Meter

The field strength meter shall have a probe with omnidirectional pickup characteristics and a 10 cm (4 in) diameter protective sphere, and shall be capable of measuring E-field power densities from 0.01 mW/cm^2 with an uncertainty no greater than $\pm 1 \text{ dB}$.

§1221.48 Isotropic Probe

The isotropic probe shall have sensor antennas consisting of three orthogonal dipoles enclosed in a 10 cm (4 in) diameter protective sphere, a minimum detectable power density level of 0.01 mW/cm^2 over the frequency range of 10 to 40 GHz, and high resistance between the sensor and metering units.

§1221.49 Photometer

The photometer shall incorporate a photopic response which closely approximates the Commission International de l'Eclairage (CIE) luminous efficiency function and have optics which allow the measurement of circular areas as small as 0.01 cm (0.004 in) in diameter. The photometer shall have a full scale sensitivity of at least 0.34 candela per square meter (cd/m^2) (0.01 foot-lambert). Measurement uncertainty of the calibrated photometer shall be less than 5 percent of the reading.

§1221.50 Simulator Test Range

The simulator test range shall have the capability of mounting the radar device in an interference free environment and the means of generating modulation reflection signals as pseudo Doppler audio signals. It shall be able to produce simulated patrol and target vehicle speeds simultaneously. The simulator test range shall consist of a mounting bench, two audio signal generators and microwave single-side-band (SSB) modulator. The audio generators shall operate from 300 to 15 000 Hz with frequency counters having an uncertainty of less than 1 part in 10^6 and shall have a calibrated output with an uncertainty no greater than ± 2 dB. If integral frequency counters are not included, separate counters with the required accuracy shall be used. The SSB modulator shall be capable of generating SSB modulation for frequencies of 300 to 16 000 Hz, and test personnel shall be able to monitor visually the microwave signal level and the modulator balance adjustment.

§1221.51 Line Impedance Stabilization Network (LISN)

The LISN, constructed as in figure 1 (see page A-2) with shielded terminals, shall be capable of simultaneously interfacing with the radar device, the standard supply voltage source, and the interference injection generator.

§1221.52 Isolation Transformer

The isolation transformer shall have a 4:1 impedance ratio, a frequency range of 30 Hz to 16 kHz, and the secondary winding as connected shall be capable of handling the current flow without saturating the core.

§1221.53 Pulse Generator

The pulse generator shall be capable of producing 20 V p-p across a 50 Ω output impedance with rise and fall times of less than 1 μs and pulse repetition rates to 200 to 10 000 pps.

§1221.54 Sawtooth Wave Generator

The sawtooth wave generator shall be capable of producing 20 V p-p across a 50 Ω impedance. It shall also be capable of producing a sawtooth wave having a positive-going, leading-edge, fast rise-time wave of less than 1 μ s over a frequency range of 200 to 16 000 Hz.

§1221.55 FM Signal Generator

The FM signal generator shall be capable of producing 20 mW output power at frequencies from 30 to 500 MHz and shall have an audiofrequency modulation variable from 500 to 5000 Hz, a 50 Ω output impedance, a maximum standing-wave ratio of 1.2 and a variable output level. It shall also have a deviation meter or calibrated control for determining the peak frequency deviation with an uncertainty no greater than 10 percent.

§1221.56 AM Signal Generator

The AM signal generator shall cover the 25 to 30 MHz frequency range, be capable of producing at least 20 mW output power and 99 percent modulation with frequencies from 500 to 5000 Hz, and have a 50 Ω output impedance and a maximum standing-wave ratio of 1.2. The generator should include a digital frequency counter having an uncertainty no greater than 1 part in 10^6 and an AM monitor or calibrated control for determining the AM percentage with an uncertainty no greater than 10 percent. If an integral frequency counter is not included, a separate frequency counter having the required accuracy shall be provided.

§1221.57 Power Meter

The power meter shall have 50 Ω feed-through detectors for frequencies from 20 to 500 MHz and the ability to handle powers up to 50 W with an uncertainty of 10 percent or less.

§1221.58 Stopwatch

The stopwatch shall have a 0.1 s resolution or better and a total time accumulation of at least 5 min.

§1221.59 Oscilloscope

The oscilloscope shall have a vertical input sensitivity (y-axis) of 10 mV/cm or better and a frequency response of at least 5 MHz. It shall also have a horizontal input (x-axis) having at least 20 kHz frequency response and a horizontal sweep time base resolution of 100 μ s/cm or better. It shall provide a reference voltage, having an uncertainty of 5 percent or less, for calibrating the vertical input.

§1221.60 Vibration Tester

The vibration tester shall be adjustable in frequency from 10 to 60 Hz, in a linear-sweep mode, and it shall be servo-controlled with a reference signal derived from a suitable calibrated accelerometer or other calibrated sensor. It shall also provide an adjustable simple harmonic motion in at least one plane for a total excursion of 1 mm (0.04 in).

§1221.61 Slide Whistle

The slide whistle, a wind instrument with a notched hollow tube and a variable displacement, shall be capable of producing audiofrequency notes from 500 to 3000 Hz.

PROCEDURES

§1221.71 Tuning Fork Calibration Test

Interconnect the test equipment as shown in figure 2 (see page A-3) except that a frequency counter, microphone, and amplifier may be substituted for the audiofrequency synthesizer and the oscilloscope. If used, adjust the audiofrequency synthesizer to approximately the tuning fork frequency. The tuning fork frequency is determined by multiplying the labeled tuning fork speed when expressed in km/h by 50.5183 (31.3906 when expressed in mph) for types I and II radar devices and by 115.9212 (72.0301 when expressed in mph) for types III and IV radar devices. For Ka-band radar devices, the transmitted nominal microwave frequency must be specified to determine the tuning fork frequency. For Ka-band type V and VI radar devices the tuning fork frequency is calculated by multiplying the labeled tuning fork speed expressed in km/h by 4.800890 (2.983135 when expressed in mph) times the nominal microwave frequency expressed in gigahertz (i.e., frequency in megahertz divided by 1000) of the particular radar device.

Strike the tuning fork on a nonmetallic object, wait 3 s, then hold it in front of the microphone while adjusting the synthesizer frequency to obtain a stationary, circular, Lissajous pattern on the oscilloscope. Record the tuning fork frequency directly from the synthesizer dials. Divide the synthesizer frequency, or the frequency as measured by the counter, by the appropriate constant given above to obtain the speed corresponding to the measured frequency of the tuning fork.

§1221.72 Radar Device Tuning Fork Test

(a) All Radar Devices. Place the radar device in the stationary mode of operation, orienting the antenna so that no moving targets are present. Activate the tuning fork by striking it on a nonmetallic object and hold it 2.5 to 10 cm (1 to 4 in)

in front of the antenna with the flat side parallel to the direction of propagation. The radar must display the speed corresponding to the tuning fork frequency within the allowable tolerance in the target vehicle speed window.

(b) Types II, IV, and VI Radar Devices (Opposite Direction Moving Mode). Place the radar in the moving mode of operation, orienting the antenna so that no moving targets are available to the radar. Activate the lower speed tuning fork by striking it on a nonmetallic object and hold it 2.5 to 10 cm (1 to 4 in) in front of the antenna with the flat side parallel to the direction of propagation. The radar should display the tuning fork speed in the patrol vehicle speed window. Strike the higher speed tuning fork on a nonmetallic object and place in front of the antenna alongside the lower speed tuning fork. The speed corresponding to the low-speed tuning fork frequency must remain in the patrol vehicle speed display window and the target vehicle speed display must indicate the difference in speed between the two tuning forks within the allowable tolerance.

(c) Types II, IV, and VI Radar Devices (Same Direction Moving Mode). Place the radar in the following mode of operation, orienting the antenna so that no moving targets are available to the radar. Activate the higher speed tuning fork by striking it on a nonmetallic object and hold it 2.5 to 10 cm (1 to 4 in) in front of the antenna with a flat side parallel to the direction of propagation. The radar must display the speed corresponding to the tuning fork frequency within the allowable tolerance in the patrol display window. Strike the lower speed tuning fork on a nonmetallic object and place in front of the antenna alongside the high speed tuning fork. The speed corresponding to the high speed tuning fork frequency must remain in the patrol vehicle speed display window and the target vehicle speed display must indicate the sum of the two tuning forks.

§1221.73 Microwave Transmission Tests

(a) Transmission Frequency and Frequency Stability Test

(1) Place the radar device in the anechoic chamber and connect the test equipment as shown in figure 3 (see page A-4). Position the pickup horn antenna in the radar beam a sufficient distance away from the radar device to prevent overdriving the microwave frequency counter. Adjust the standard supply voltage to its nominal value and record the microwave frequency.

(2) Reduce the standard supply voltage by 20 percent of its nominal value (8 percent for NiCd battery pack) or to the manufacturer's low voltage value, allow it to stabilize for 2 min, and repeat the above procedure.

(3) Repeat the procedure for a change in standard supply voltage of +20 percent.

(b) Input Current Test. Place the radar device in the anechoic chamber and connect the test equipment as shown in figure 4 (see page A-5). Refer to §1221.31(c) regarding the standard supply. Adjust the standard supply voltage to its nominal value, strike the tuning fork, and record the input current and voltage. Vary the standard supply voltage +20 percent and record the change in input current. Repeat for a supply voltage of -20 percent (-8 percent for NiCd battery pack) of the nominal value.

(c) Radiated Output Power Stability Test. Position the radar device on a vertical test stand in the anechoic chamber with the antenna pointed upward, and connect the test equipment as shown in figure 5 (see page A-6). Mount the isotropic probe of the field intensity meter 50 to 100 cm (20 to 40 in) from the radar antenna in the longitudinal axis of the radar beam. Adjust either the radar or the probe horizontally to position the probe in the center of the principal axis of the beam (maximum probe reading). Record the distance between the antenna aperture and the isotropic probe, adjust the standard supply voltage to its nominal value and record the field strength of the microwave output signal. Vary the standard supply voltage ± 20 percent (-8 percent for NiCd battery pack) and record the change in microwave output power density.

(d) Antenna Horizontal Beamwidth Tests. Use either the following test (1) or test (2), as appropriate:

(1) Antenna Horizontal Beamwidth Test. Position the radar device on a vertical test stand in the anechoic chamber, with the antenna pointed upwards, and connect the test equipment as shown in figure 5 (see page A-6). Mount the isotropic probe of the field intensity meter 50 to 100 cm (20 to 40 in) above the radar antenna. Energize the radar using the standard supply voltage and allow it to stabilize for 2 min. Adjust the position of the radar device on the test stand until the probe is in the center of the antenna beam (maximum power), then adjust the height of the probe for a full scale or reference level on a sensitive scale of the field strength meter, maintaining the probe in the antenna far-field region. Record the field intensity and the distance between the antenna and the probe. Using caution not to accidentally rotate it, move the radar device to the right along a line parallel to the horizontal axis of the radar device until half-power is indicated on the meter and carefully mark the position of the radar device. Move the radar device to the left of the probe along the same line until half-power is again indicated on the meter. Mark this point and measure the distance between the half-power points.

For a linearly polarized antenna, calculate the half-power beamwidth, A, using the following equation to correct for the change in radial distance.

$$A = 2F \text{ Arctan } (D/2R)$$

where A is the angular half-power beamwidth, F is a factor to correct for the change in radius (from the graphed curve of fig. 6), D is the average perpendicular distance between the half-power points P_1 (figure 6, see page A-7) and R is the radius from the front of the antenna to the point at which the maximum power density was measured.

For a circularly polarized antenna, move the radar device along a line parallel to the vertical axis of the radar device, measure the distance between these half-power points. Average the distances between the horizontal and vertical half-power readings and calculate the half-power beamwidth using the above equation to correct for any change in radial distance.

(2) Antenna Horizontal Beamwidth Test (Alternate Method for Circularly Polarized Radar Devices Only). Position the radar device on a turntable in the anechoic chamber, energize it using the standard supply voltage and allow it to stabilize for 2 min. Position a pickup horn antenna on the maximum power axis of the radar device antenna. Locate the horn in the far-field region at a distance close enough to indicate full scale or a reference level on a sensitive scale of the power meter. Record the protractor angle indication on the radar mounting turntable. Rotate the turntable with the radar until the power meter indicates one-half the power read at the center of the beam, record the turntable angle and then rotate the turntable back through center, continuing until the power meter again indicates one-half the power read at the center and record the turntable angle. The change in the angle readings of the turntable between the two half-power points shall be taken as the antenna beamwidth measurement.

(e) Antenna Near-Field Power Density Test. Connect the radar device to the test equipment as shown in figure 7 (see page A-8). Being careful not to vary the distance from the antenna, use the isotropic probe to search for the maximum signal strength in the plane 5 cm (2 in) from the antenna aperture or lens face of the antenna and perpendicular to the longitudinal axis of the radar beam. Move the probe to obtain the maximum reading and record it. For a NiCd battery powered radar device designed to accept an optional 12 V automotive adapter, repeat this test utilizing the adapter and a standard supply voltage of 13.6 V.

(f) Standby/Operate Switch. When a radar unit is so equipped, place the hand-held radar device in the stationary mode

and connect as in figure 7 (see page A-8) to the standard supply voltage and energize it. Allow the radar device to stabilize for 2 min then, using the isotropic probe and field intensity meter, verify that no rf power is transmitted unless the standby/operate switch is held depressed. Verify that transmission commences without undue delay when the switch is depressed, and ceases when the switch is released. Check that the standby/operate switch cannot be locked in the transmit position.

§1221.74 Environmental Tests

(a) Operational Temperature Test. Place the radar device, with the power off, in the environmental chamber and adjust the chamber to the required low temperature $\pm 2^{\circ}\text{C}$ ($\pm 3.6^{\circ}\text{F}$). Allow the radar device to reach thermal equilibrium and maintain it at this temperature for 30 min. Using protective gloves, remove the radar device from the environmental chamber, place it in the anechoic chamber and connect it to the standard supply voltage. After energizing, wait 2 min before performing any measurements. The radar shall meet the requirements of §1221.17(a) within 15 min of operation. Repeat the above procedure at the required high temperature $\pm 2^{\circ}\text{C}$ ($\pm 3.6^{\circ}\text{F}$).

(b) Operational Humidity Test. Place the radar device, with the power off, in the environmental chamber. Adjust the relative humidity to a minimum of 90 percent at 37°C (99°F) and maintain the radar device at these conditions for at least 8 h. Remove the radar device from the chamber, place it in the anechoic chamber and connect it to the standard supply voltage. After energizing, wait 2 min before performing any measurements. The radar device shall meet the requirements of §1221.17(b) within 15 min of operation.

(c) Vibration Test

(1) Fasten the radar device to the vibration tester using a rigid mounting fixture. Perform a two-part test for a total of 30 min in each of three directions, namely the directions parallel to both axis of the mounting and perpendicular to the plane of the mounting.

(2) First subject the radar device to three 5 min cycles of simple harmonic motion having an amplitude of 0.38 mm (0.015 in) [total excursion of 0.76 mm (0.03 in)] applied initially at a frequency of 10 Hz and increased at a uniform rate to 30 Hz in 2.5 min, then decreased at a uniform rate to 10 Hz in 2.5 min. Conduct the appropriate radar device tuning fork test (§1221.72) during the last 5 min cycle.

(3) Then subject the radar device to three 5 min cycles of simple harmonic motion having an amplitude of 0.19 mm (0.0075 in) [total excursion of 0.38 mm (0.015 in)] applied

initially at a frequency of 30 Hz and increased at a uniform rate to 60 Hz in 2.5 min, then decreased at a uniform rate to 30 Hz in 2.5 min. Conduct the appropriate radar device tuning fork test (§1221.72) during the last 5 min cycle.

(4) Repeat this procedure for each of the other two directions.

§1221.75 Low Supply Voltage Test

Connect the radar device to the standard supply voltage as shown in figure 4 (see page A-5) [cf §1221.31(c)] and energize it in the stationary mode. Allow the radar device to stabilize for 2 min, then conduct the appropriate radar device tuning fork test (§1221.72) and measure the radar speed generated by the tuning fork frequency. Continue to measure the radar speed and decrease the supply voltage at the rate of approximately 0.2 V/s until the low-voltage alert is activated. Record the supply voltage level. Verify that no erroneous speed reading is present. Increase the supply voltage until the low voltage indicator is deactivated, and again conduct the appropriate radar device tuning fork test to verify that the radar device displays the same speed reading as at standard supply voltage.

Also, for NiCd powered radar devices designed to accept a 12 V automotive adapter, verify that when using this adapter the device works properly down to the low voltage alert on the radar device.

§1221.76 Doppler Audio Tests

Each time a test method requires that the radar device be connected to the simulator, the radar device must also be connected to the standard supply voltage source and properly aligned on the simulator. See figure 8 (see page A-9) for a block diagram of this measurement setup. The following procedures shall be followed:

(a) Audio Output and Volume Control Test

(1) Connect the radar device to the simulator, energize it in the stationary mode and disable the squelch function. Establish a simulated target and vary the target speed to verify that the Doppler audio signal is correlated with the target speed. In a single target situation, stationary mode, the Doppler audio signal should be a single clear tone. Move a metal plate in the radar beam without interrupting the signal beam and ascertain that the interference motion from the plate is heard in the Doppler audio signal. For types II, IV, and VI radar devices, switch to moving mode operation and use the simulator to establish a simulated moving mode situation. Vary the target speed control and verify that the simulated target Doppler audio

signal is correlated with the target speed, whether the patrol Doppler audio signal is present or not.

(2) Vary the audio volume adjustment control.

(b) Audio Squelch and Squelch Override Test

(1) Connect the radar device to the simulator and energize it in the stationary mode with no target present. Verify that the audio output is squelched.

(2) Disable the squelch function and move a metal plate within the radar beam and ascertain that this motion is heard in the Doppler audio signal.

(c) Audio Track-Through-Lock Test

(1) Connect the radar device to the simulator, energize it in the stationary mode with the Doppler audio signal squelched. Establish a simulated target, actuate the speed lock switch and verify that the Doppler audio signal continues uninterrupted. Increase the simulated target speed and verify the Doppler audio signal is correlated with the target speed.

(2) Repeat the above procedure using a decreased simulated target speed.

(3) For types II, IV, and VI radar devices switch to the moving mode of operation, establish a simulated fixed patrol speed and a variable target speed and repeat the above procedure.

§1221.77 Speed Monitor Alert Test

Verify that the radar device does not have a speed monitor alert capability.

§1221.78 Power Surge Test

Conduct the following test on any devices having a standby capability. Adjust all range sensitivity controls and audio volume controls to maximum for these tests. Connect the radar device to the simulator. Place the radar device in the stationary mode, establish a simulated target of 80 km/h (50 mph), and switch the device to standby mode. Turn the device from standby to on and verify that there are no erroneous readings. Repeat this three times. For types II, IV, and VI radar devices, switch to the moving mode and repeat the above procedure.

§1221.79 Speed Display Tests

Each time a test method requires that the radar device be connected to the simulator, the radar device must also be connected to the standard supply voltage source and properly aligned on the simulator. See figure 8 (see page A-9) for a block diagram of this measurement setup. Activate the radar device in the stationary mode, determine the minimum target signal level necessary to establish a simulated 80 km/h (50 mph) target speed, then increase the simulated target signal level by 3 dB (1.5 dB if using a microwave attenuator). Turn the simulated signal off and proceed with each of the tests.

When moving mode signals are needed, set the simulated closing speed signal to zero, activate the radar device in the appropriate moving mode, determine the minimum patrol signal level necessary to establish a simulated 88 km/h (55 mph) patrol speed, then increase the simulated patrol signal level by 10 dB (5 dB if using a microwave attenuator). Turn the simulated patrol signal off and proceed with each of the tests.

(a) Display readability tests. Position the radar device with the illuminated face perpendicular to the optical axis of the photometer as shown in figure 9 (see page A-12). Position a light source at an angle of 30° from the perpendicular such that 10 780 lux (lumens per square meter) (1000 fc) of illumination will be measured across the face of the display. Turn on the display using the standard supply voltage and use a tuning fork to place a speed reading on the display. Lock in the reading and darken the room. Vary the intensity of the display to obtain the maximum luminance contrast. Use the photometer to measure the luminance of an individual character, at either a bar or a single dot, and its background. Repeat this measurement for three locations representing, if possible, the left, center and right portions of the display. Separately average the luminance values for the character and for the background. Calculate the daylight luminance contrast, C, using the formula

$$C = \frac{L_1 - L_2}{L_2} ,$$

or

$$C = \frac{L_2 - L_1}{L_1}$$

if L_2 is greater than L_1 , where L_1 is the average luminance of the display element, and L_2 is the average luminance of the background immediately surrounding the display element. Repeat for an illumination angle of 45° and then for 60°. All three calculated luminance contrast values must be within the specification.

(b) Display Speed Lock Tests

(1) These tests may be performed in conjunction with the display clear test [paragraph (c) of this section] for convenience. Connect the radar device to the simulator and establish a simulated target. Verify that the radar device has no automatic speed lock capability. Place the radar device in the stationary mode and activate the speed lock switch to retain the target vehicle speed reading. Increase the target speed, then discontinue the simulated target and verify that the target speed display has retained the correct speed reading.

(2) Clear the radar device and again establish a simulated target, but do not activate the speed lock switch. Discontinue the simulated target, wait for the display to blank, and then activate the speed lock switch. Verify that the target speed display remains blank.

(3) For types II, IV, and VI radar devices establish both a simulated target and a simulated patrol vehicle speed. Proceed as above except that both the target speed display and the patrol speed display must be observed and neither can be inhibited except after lock.

(c) Display Clear Test

(1) Connect the radar device to the simulator, energize it in the stationary mode, establish a simulated target, then turn off the simulated signal. Activate any one of the control switches (on, off, standby, test, etc.) on the radar device except the speed lock switch and verify that the previous speed reading has not been preserved. Repeat for each control switch on the radar device. For types II, IV, and VI radar devices, switch to the opposite direction moving mode and repeat the above procedure. Repeat for same direction moving mode (if appropriate).

(2) With the radar device still connected to the simulator, again establish a simulated target. Lock in this speed reading using the speed lock switch. Activate any one of the control switches on the radar device except standby and test, and verify that the previous speed reading has not been preserved. Repeat for each control switch on the radar device.

(d) Internal Circuit Test. Activate the radar device and perform the internal circuit test in accordance with the instructions of the manufacturer. Verify that only correct readings are displayed, and that all readings are cleared automatically when the test is completed. Repeat the internal circuit test a second time and attempt to actuate the speed lock switch while readings are displayed. Verify that these readings are not retained by the display.

(e) Speed Display Transfer Test. Connect the radar device to the simulator, set it to the moving mode and establish an opposite direction moving mode simulated patrol and target speeds. Activate the speed-lock switch and discontinue the simulated signals. Using each of the available controls, attempt to transfer the patrol speed reading to the target speed display. Repeat for same direction moving mode (if appropriate).

(f) Signal Processing Channel Sensitivity Tests

(1) Connect the radar device to the simulator and establish a 56 km/h (35 mph) simulated target speed. Do not move the radar device for the remainder of this test. Place the radar device in the stationary mode, increase the target signal by adjusting the generator output or audio attenuator and record the target speed minimum signal level needed to acquire the target. Repeat for target speeds of 32 km/h (20 mph) or the lowest target speed specified by the manufacturer, whichever is lower, to 144 km/h (90 mph) at 16 km/h (10 mph) increments. Continue this test in 16 km/h (10 mph) increments up to the maximum target speed specified by the manufacturer.

(2) For types II, IV, and VI radar devices, place the radar device in the moving mode (opposite direction moving mode if appropriate), establish a 40 km/h (25 mph) simulated patrol vehicle speed and then increase the patrol speed signal level by 10 dB (5 dB if using a microwave attenuator). Establish a 64 km/h (40 mph) simulated target, acquire it and record the target speed minimum signal level needed to reacquire the target. Repeat for target speeds of 96 to 144 km/h (60 to 90 mph) at 16 km/h (10 mph) increments. Repeat the procedure for a simulated patrol vehicle speed of 80 km/h (50 mph) and target speeds of 96 to 144 km/h (60 to 90 mph) at 16 km/h (10 mph) increments. Continue this test at 16 km/h (10 mph) increments up to the maximum target speed specified by the manufacturer.

(3) For types II, IV, and VI radar devices having same direction moving mode capability, place the radar device in the faster-target, same direction moving mode, establish a 64 km/h (40 mph) simulated patrol speed, then increase the patrol speed signal level by 10 dB (5 dB if using a microwave attenuator). Establish a 16 km/h (10 mph) simulated difference Doppler signal, acquire the 80 km/h (50 mph) simulated target speed, and record the target speed minimum signal level needed to reacquire the target. Repeat for a simulated difference Doppler signal of 40 km/h (25 mph), giving a simulated target display of 104 km/h (65 mph).

Repeat the above procedure at a simulated patrol speed of 88 km/h (55 mph) and target speeds of 104 to 128 km/h (65 to 80 mph) at 8 km/h (5 mph) increments. Verify that the radar device will display a 96 km/h (60 mph) target.

Then, place the radar device in the slower-target, same direction moving mode and establish an 88 km/h (55 mph) simulated patrol speed. Increase the level 10 dB as above, establish a 16 km/h (10 mph) simulated difference Doppler signal, acquire the 72 km/h (45 mph) simulated target speed, and record the target speed minimum signal level needed to reacquire the target. Repeat for a simulated difference Doppler signal of 40 km/h (25 mph) giving a simulated target display of 48 km/h (30 mph).

Repeat this procedure at a simulated patrol speed of 88 km/h (55 mph) and target speeds of 48 to 72 km/h (30 to 45 mph). Verify that the radar device will display a 80 km/h (50 mph) target.

(g) Target Channel Low and High Speed Display Tests. To establish initial signal levels and avoid overdriving the simulator circuitry diodes, follow the guidelines set forth within the introductory paragraph to §1221.79. Simulator signal levels may be varied as needed during tests (g) and (h).

(1) Connect the radar device to the simulator. With radar device in off or standby, establish a simulated target traveling at the required low speed or the lowest speed specified by the manufacturer, whichever is lower. Switch the radar device to the stationary mode to verify that it will acquire this target and measure its speed. For types II, IV, and VI radar devices, establish a simulated patrol speed of 32 km/h (20 mph) or the lowest speed specified by the manufacturer, whichever is lower. Switch the radar device to the opposite direction moving mode, increase the patrol speed signal to 10 dB above the acquisition level and repeat above procedure. Always maintain the closing speed signal level below the patrol speed signal level and avoid overdriving the simulator with target or patrol speed signals. Repeat for same direction moving mode (if appropriate). If simulated patrol speed and simulated closing speed are harmonics of each other, increase patrol speed by 3.2 km/h (2 mph).

(2) Switch the radar device to the stationary mode and repeat this procedure using the required high speed target speed or highest speed specified by the manufacturer, whichever is higher.

(3) For types II, IV, and VI radar devices, with a patrol vehicle speed of 112 km/h (70 mph) and a simulated target traveling at 160 km/h (100 mph), verify that the target signal processing channel will process and display the correct speed readings. Always maintain the closing speed signal level below the patrol speed signal level and avoid overdriving the simulator with target or patrol speed signals. For type IV radar devices, change the closing speed to 338 km/h (210 mph), with a maximum patrol speed of 88 km/h (55 mph). Then slowly increase the closing speed to 362 km/h (225 mph.) Verify that the radar

device will not process and display any target speed reading over this range of closing speeds. If simulated patrol speed and simulated closing speed are harmonics of each other, decrease patrol speed by 3.2 km/h (2 mph).

(h) Patrol Channel Speed Display

(1) Low and High Speed Tests. Connect the radar device to the simulator. With the radar device in off or standby, establish a simulated target speed signal at the required low speed. Switch the radar device to the opposite direction moving mode. Adjust the patrol speed signal to the acquisition level and verify that it will acquire and measure patrol speeds down to the required low speed. With the radar device still in the opposite direction moving mode, establish a patrol speed of 112 km/h (70 mph) and verify that the radar device will acquire and measure patrol speeds up to the required high speed. Repeat for same direction moving mode (if appropriate).

(2) Patrol Vehicle Speed Change Test

(i) Connect the radar device to the simulator and establish a patrol speed of 32 km/h (20 mph). Place the radar device in the opposite direction moving mode and display the correct patrol speed. Increase the simulator patrol speed at a rate of 4.8 km/h per second (3 mph per second) for 5 s and verify that the patrol speed display reading agrees with the simulated patrol speed during this 5 s period. Repeat this procedure for initial patrol speeds of 48 and 64 km/h (30 and 40 mph). Repeat for same direction moving mode (if appropriate).

(ii) With the radar device still connected to the simulator, establish a patrol speed of 88 km/h (55 mph). Place the radar device in the opposite direction moving mode and display the correct patrol speed. Decrease the simulator patrol speed at a rate of 4.8 km/h per second (3 mph per second) for 5 s and verify that the patrol speed reading agrees with the simulated patrol speed during this 5 s period. Repeat this procedure for an initial patrol speed of 64 km/h (40 mph).

(i) Auxiliary Display Tests

(1) Connect the radar device together with the auxiliary printer or remote display module to the simulator and conduct the display speed lock test (paragraph (b) of this section) and the display clear test (paragraph (c) of this section). Verify that the remote module displays are cleared when reconnected to the radar device.

(2) With the radar device still connected to the simulator, establish a simulated target, actuate the speed lock switch and the printer function. Verify that the printout includes the items required by §1221.21(i).

§1221.80 Electromagnetic Interference Tests

Connect the radar device to the simulator and to the other test equipment as shown in figure 10 (see page A-13) [cf §1221.31(c)]. Activate the radar device in the stationary mode, determine the minimum signal level necessary to establish a simulated 80 km/h (50 mph) target, then increase the simulated signal level by 3 dB (1.5 dB if using a microwave attenuator). Turn the simulated signal off, and proceed with each of the tests in paragraphs (a) through (d) of this section.

For a NiCd powered radar device designed to accept an optional 12 V automotive adapter, repeat the electromagnetic interference tests utilizing this adapter and a standard supply voltage of 13.6 V. Connect the injection isolation transformer or LISN in series with the standard supply and automotive adapter for these interference tests.

(a) Vehicle Alternator Interference Test

(1) With the pulse generator connected such that the pulse signals are impressed on the radar device power line, set the generator output to 1 V p-p or 7.5 percent of the standard supply voltage in use (whichever is lower), as measured by the oscilloscope, at a pulse repetition rate of 200 pps with a pulse width of 10-20 μ s. With the radar device still in the stationary mode, establish a simulated target of 64 km/h (40 mph) and slowly vary the generator frequency from 200 to 10 000 pps and back to 200 pps.

(2) For types II, IV, and VI radar devices, switch to the opposite direction moving mode, turn off the pulse generator, and determine the minimum signal level necessary to establish a patrol speed of 80 km/h (50 mph). Then increase this level by 10 dB (5 dB if using a microwave attenuator). Establish a target speed of 96 km/h (60 mph) (3 dB above a minimum target signal), reset the pulse generator to 1 V p-p or 7.5 percent of the standard supply voltage in use (whichever is lower) and repeat the procedure in (1) above. Verify that no erroneous readings appear at any time. Repeat for same direction moving mode (if appropriate).

(3) Repeat (1) and (2) above using a constant pulse repetition rate of 1500 pps while slowly varying the pulse amplitude from 0 to 1 V p-p or 7.5 percent of the standard supply voltage in use (whichever is lower) and back to 0 V, as measured

at the oscilloscope. Repeat (1) and (2) above using a constant 3100 pps.

(b) Vehicle Ignition, Air Conditioner/Heater Motor and Windshield Wiper Motor. Disconnect the pulse generator (figure 10, see page A-13) and replace it with the sawtooth wave generator as shown in figure 11 (see page A-14) [cf §1221.31(c)], such that sawtooth wave signals are impressed on the radar device power line. Place the radar device in the stationary mode, establish a simulated target of 64 km/h (40 mph), then increase the simulated signal level by 3 dB above a minimum target signal. Set the generator output to 1 V p-p or 7.5 percent of the standard supply voltage in use (whichever is lower) as measured on the oscilloscope at a frequency of 200 Hz. Slowly vary the generator frequency from 200 to 10 000 Hz and back to 200 Hz. Verify that no erroneous readings appear at any time.

For types V and VI radar devices, repeat this procedure while slowly varying the sawtooth generator frequency from 15 000 to 16 000 Hz and back to 15 000 Hz, verifying that no erroneous readings appear. Pay particular attention to 15 750 Hz.

For types II, IV, and VI radar devices, switch to the opposite direction moving mode, turn off the sawtooth wave generator and establish a patrol speed of 80 km/h (50 mph) (10 dB above minimum patrol signal) and a target speed of 96 km/h (60 mph). Then increase the simulated signal level by 3 dB, reset the sawtooth wave generator to 1 V p-p or 7.5 percent of the standard supply voltage in use (whichever is lower) and repeat the above procedures. Verify that no erroneous readings appear at any time. Repeat for same direction moving mode (if appropriate). For type VI radar devices repeat procedures for frequencies from 15 000 to 16 000 Hz and back to 15 000 Hz.

(c) Police FM Transceiver Interference Test

(1) Connect the FM signal generator to the line impedance stabilization network, as shown in figure 12 (see page A-15) [cf §1221.31(c)], such that the rf signals are impressed on the radar device power line. Place the radar device in the stationary mode, establish a simulated target of 64 km/h (40 mph), then increase the simulated signal level by 3 dB, set the generator frequency deviation to 5 kHz. Set the generator to a frequency of 160 MHz with an output of 10 mW, as measured by the power meter, with no more than 1 mW reflected power. Slowly vary the modulation frequency from 200 to 10 000 Hz and back to 200 Hz. Verify that no erroneous readings appear at any time.

(2) For types II, IV, and VI radar devices, switch to the opposite direction moving mode, turn off the FM signal generator, establish a patrol speed of 80 km/h (50 mph) (10 dB above minimum patrol signal) and a target speed of 96 km/h

(60 mph). Then increase the simulated signal level by 3 dB, turn on the FM signal generator, and repeat the above procedure. Verify that no erroneous readings appear at any time. Repeat for same direction moving mode (if appropriate).

(3) Repeat (1) and (2) above using a constant modulation frequency of 1500 Hz while slowly varying the FM signal generator output from 0 to 10 mW and back to 0 mW. Repeat (1) and (2) above using a constant modulation frequency of 3100 Hz.

(4) Repeat the entire test for frequencies of 40 and 460 MHz.

(d) Citizens Band (CB) AM Transceiver Interference Tests

(1) Connect the AM signal generator to the line impedance stabilization network, as shown in figure 12 (see page A-15) [cf §1221.31(c)], such that the rf signals are impressed on the radar device power line. Place the radar device in the stationary mode, establish a simulated target of 64 km/h (40 mph), then increase the simulated signal level by 3 dB. Set the generator to a frequency of 27 MHz with an output of 5 mW, as measured by the power meter, with no more than 1 mW reflected power, and adjust the generator modulation to 99 percent. Slowly vary the modulation frequency from 200 to 10 000 Hz and back to 200 Hz. Verify that no erroneous readings appear at any time.

(2) For types II, IV, and VI radar devices, switch to the opposite direction moving mode, turn off the AM signal generator, establish a patrol speed of 80 km/h (50 mph) (10 dB above minimum patrol signal) and a target speed of 96 km/h (60 mph). Then increase the simulated signal level by 3 dB, turn on the AM signal generator, and repeat the above procedure. Verify that no erroneous readings appear at any time. Repeat for same direction moving mode (if appropriate).

(3) Repeat (1) and (2) above using a constant modulation frequency of 1500 Hz while slowly varying the AM signal generator output from 0 to 5 mW and back to 0 mW. Repeat (1) and (2) above using a constant modulation frequency of 3100 Hz.

§1221.81 Radar Device Operational Tests

Install the radar device in the patrol vehicle in accordance with the manufacturers instructions, using extreme care in positioning the antenna. The patrol vehicle shall be of the type normally used for law enforcement purposes, with heavy duty components. It shall have at least one standard police FM transceiver and an antenna installed in accordance with the

instructions provided by the transceiver manufacturer. This test must be conducted in an environment free of extraneous moving targets such as large ventilation fans.

For a NiCd powered radar device designed to also accept an optional 12 V automotive adapter, perform the police FM transceiver interference test (a) utilizing the NiCd battery pack and then repeat the test utilizing the automotive adapter.

The citizens band (CB) AM transceiver interference test (b) and the adjacent vehicle radio interference test (c) are performed utilizing only the NiCd battery pack.

(a) Police FM Transceiver Interference Test

(1) Start the patrol vehicle engine and set it to a fast idle. Wait 30 s, place the radar device in the stationary mode and switch on the FM transceiver. Track a just-acquired distant target traveling at a speed of 80 km/h (50 mph), activate the push-to-talk switch and use the slide whistle to transmit tones via the microphone. Slowly vary the tone of the slide whistle from 500 to 3000 Hz and back to 500 Hz, observing the target speed display for possible erroneous readings. Repeat two more times.

(2) Turn off the FM transceiver and repeat the procedure using a handheld FM transceiver with an integral antenna and an output power of 2 W or more positioned at the patrol vehicle driver's location.

(b) Citizens Band (CB) AM Transceiver Interference Test.

Mount a 4 W minimum output CB transceiver in a typical front seat location and install the antenna as recommended by the manufacturer. Connect the CB transceiver power leads to the vehicle battery or the ignition switch circuitry but not to the cigarette lighter. Start the patrol vehicle engine and set it to a fast idle. Place the radar device in the stationary mode and track a just-acquired distant target traveling at a speed of 80 km/h (50 mph). Switch on the CB transceiver, set it to channel 20, activate the push-to-talk switch, and use the slide whistle to transmit tones via the microphone. Slowly vary the tone from 500 to 3000 Hz and back to 500 Hz observing the target speed display for possible erroneous readings. Repeat for channels 1 and 40.

(c) Adjacent Vehicle Radiofrequency Interference Test

(1) Start the patrol vehicle engine and set it to a fast idle. Place the radar device in the stationary mode and track a just-acquired distant target traveling at a speed of 80 km/h (50 mph). From a distance of at least 15 m (50 ft),

slowly drive a second vehicle equipped with a police FM transceiver of at least 50 W of output power and a matching antenna past the patrol vehicle passing within 3 m (10 ft) of it. Use the slide whistle to transmit tones between 500 and 3000 Hz from this transceiver until reaching a point 50 ft away from the patrol vehicle. Note any erroneous readings on the radar device display. Turn the second vehicle around and repeat the above procedure, passing within 3 m (10 ft) of the patrol vehicle on its other side, again using the slide whistle to transmit modulating tones from 500 to 3000 Hz, and observing the radar speed display.

(2) Turn off the FM transceiver, mount a 4 W minimum output power CB transceiver powered by the vehicle electrical system in the second vehicle, and repeat the above procedure.

§1221.82 Speed Accuracy Test

(a) Establish a measured distance of at least 800 m (2640 ft) on an open, level location away from other moving targets. Turn on the radar device, place it in the stationary mode, and drive the patrol vehicle over the measured distance at a constant speed, measuring the elapsed time with a stopwatch while recording the patrol speed reading and the speedometer readings. Repeat the procedure twice in each direction, maintaining the same speed for all four runs. Use the stopwatch average time to determine the true patrol vehicle speed and use this speed to calculate the patrol vehicle speedometer correction factor and the radar device speed correction factor. Repeat this procedure for speeds of 32, 72, and 96 km/h (20, 45, and 60 mph).

(b) For types II, IV, and VI radar devices, switch to the opposite direction moving mode of operation and repeat this procedure to obtain the appropriate correction factor. Repeat for the same direction moving mode (if appropriate).

(c) Switch the radar device to the stationary mode of operation and position the radar equipped patrol vehicle near one end of the measured test range. Drive a target vehicle through a measured distance of at least 400 m (1312 ft) at a constant speed, measuring the elapsed time with a stopwatch, recording the exact distance and the speedometer reading and measuring target vehicle speed with the radar device. Repeat one time, then move the patrol vehicle to the opposite end of the measured range. Repeat the procedure twice in this direction, again recording the stopwatch elapsed time, speedometer reading and radar speed reading. Calculate the true target vehicle speed, the target vehicle speedometer correction factor and the indicated radar speed reading. Repeat this procedure for speeds of 32, 80, and 112 km/h (20, 50, and 70 mph).

(d) For types II, IV, and VI radar devices, switch the radar device to the opposite direction moving mode and station the patrol vehicle and target vehicle at least 400 m (1312 ft) apart and at opposite ends of the measured distance such that each vehicle can make a constant speed run through the same 400 m (1312 ft) portion. Make three moving mode, constant speed, approaching runs in each direction, recording the measured distance, the speedometer readings of each vehicle, and the radar device speed display reading. A stopwatch may be used to obtain the true vehicle speed. Average the six speedometer and speed display readings. Calculate the true target vehicle speed, the target vehicle correction factor and the indicated radar speed reading. Repeat this procedure using a patrol speed of 32 km/h (20 mph) and a target speed of 88 km/h (55 mph) and using a patrol speed of 88 km/h (55 mph) and a target speed of 112 km/h (70 mph).

(e) For radar devices with a same direction moving mode, switch to this mode and repeat the procedure given in (d) above.

Table 1. - Minimum Performance Requirements for Speed Measuring Radar Devices

Performance Characteristics	Minimum Requirement
A. Tuning Fork Frequency Tolerance	$\pm 1/2\%$
B. Radar Device Tuning Fork Speed Tolerance	± 2 km/h (± 1 mph)
C. Microwave Frequency	10 525 \pm 25 MHz (X-Band) 24 150 \pm 100 MHz (K-Band) 33 400 to 36 000 MHz, ± 100 MHz (Ka-Band)
D. Input Current Variation	25%
E. Radiated Output Power Variation	± 1.5 dB
F. Antenna Horizontal Beamwidth	18° max (X-Band) 15° max (K-Band) 15° max (Ka-Band)
G. Antenna Near-Field Maximum Power Density	5 mW/cm ²
H. Radar Device Speed Tolerance During Vibration	± 3 km/h (± 2 mph)
I. Low Supply Voltage	10.8 V max (automotive system) 92 \pm 3% standard supply voltage (NiCd)
J. Display Readability Contrast	2.5
K. Display Readability Height	(No requirement)
L. Target Channel Sensitivity, Stationary Mode	≤ 10 dB 56 to 144 km/h (35 to 90 mph) ≤ 5 dB 96 to 144 km/h (60 to 90 mph)
M. Target Channel Sensitivity, Opposite Direction Moving Mode	≤ 10 dB 64 to 144 km/h (40 to 90 mph) ≤ 5 dB 96 to 144 km/h (60 to 90 mph)
N. Target Channel Sensitivity Same Direction Moving Mode	≤ 10 dB ± 8 to 40 km/h (± 5 to 25 mph)
O. Target Channel Speed Displays	32 km/h (20 mph) max low speed 160 km/h (100 mph) min high speed

Table 1. Continued

Performance Characteristics	Minimum Requirement
P. Patrol Channel Speed Displays	32 km/h (20 mph) max low speed 112 km/h (70 mph) min high speed
Q. Patrol Channel Speed Changes	± 2 km/h (± 1 mph) for 4.8 km/h (3 mph) per second
R. Accuracy, Stationary Mode	+2, -3 km/h (+1, -2 mph)
S. Accuracy, Moving Mode	± 3 km/h (± 2 mph)

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APPENDIX

Figure Captions

Figure 1. Line impedance stabilization network (LISN).

Figure 2. Block diagram for tuning fork calibration.

Figure 3. Block diagram for transmission frequency and frequency stability measurements.

Figure 4. Block diagram for input current, low supply voltage and power surge measurement.

Figure 5. Block diagram for antenna beamwidth measurements.

Figure 6. Antenna beamwidth correction factor, F .

Figure 7. Block diagram for antenna near-field power density measurement.

Figure 8. Block diagram for the simulator test range used in Doppler audio, power surge, speed display, and electromagnetic interference measurements.

Figure 8a. Schematic of balanced modulator shown in figure 8.

Figure 8b. Schematic of 0-90 degree phase shifter shown in figure 8.

Figure 9. Setup for display readability measurements.

Figure 10. Block diagram for the simulated vehicle alternator interference measurement.

Figure 11. Block diagram for the simulated vehicle ignition, air conditioner/heater and windshield wiper interference measurements.

Figure 12. Block diagram for the simulated police FM transceiver and the citizens band AM transceiver interference measurements.

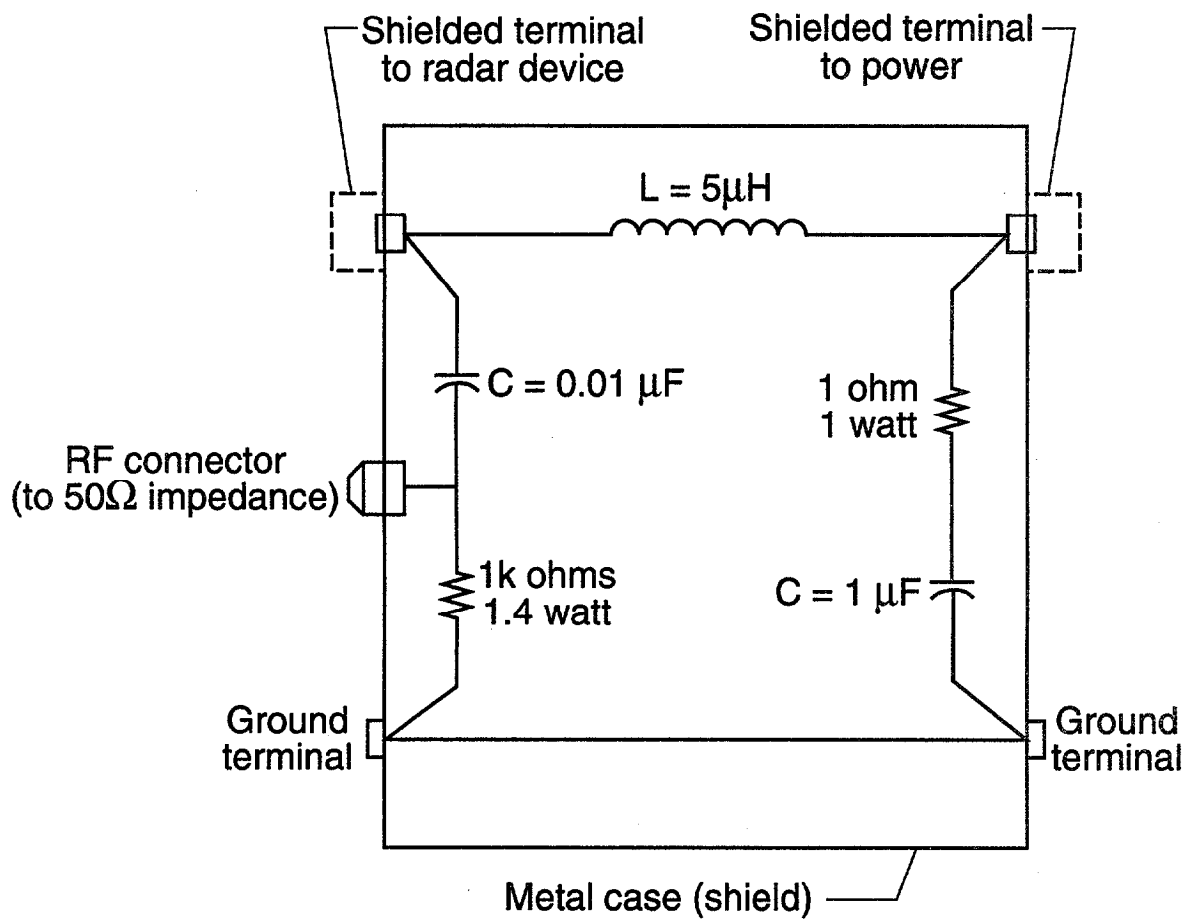


Figure 1. Line impedance stabilization network (LISN).

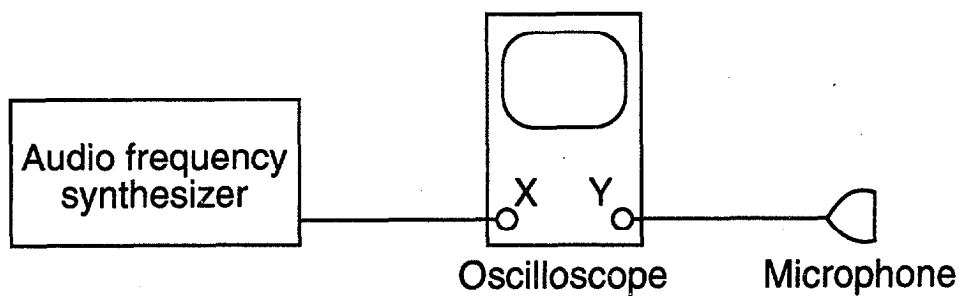


Figure 2. Block diagram for tuning fork calibration.

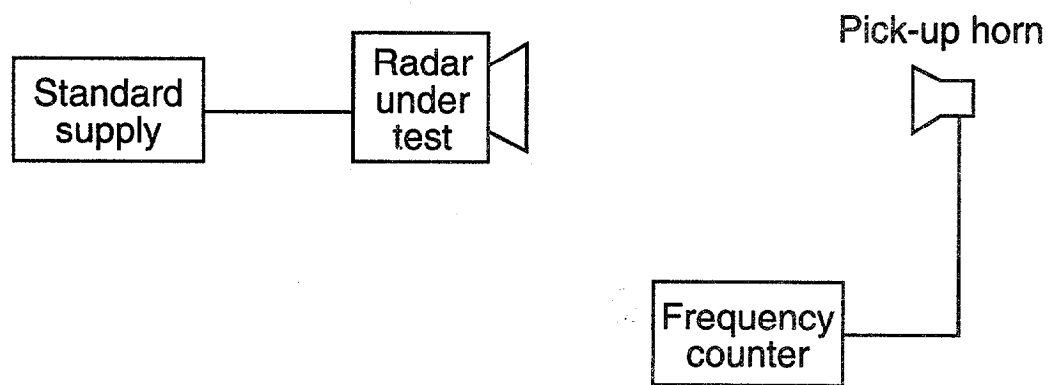


Figure 3. Block diagram for transmission frequency and frequency stability measurements.

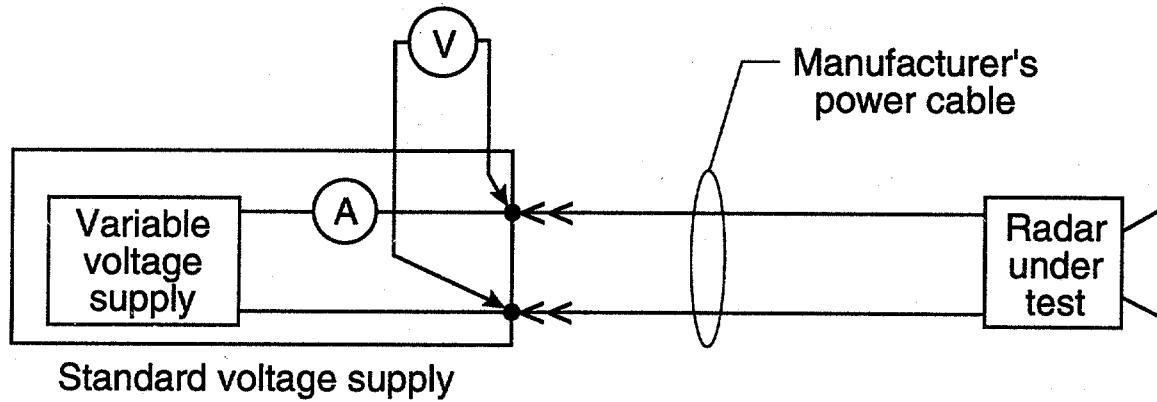


Figure 4. Block diagram for input current, low supply voltage and power surge measurement.

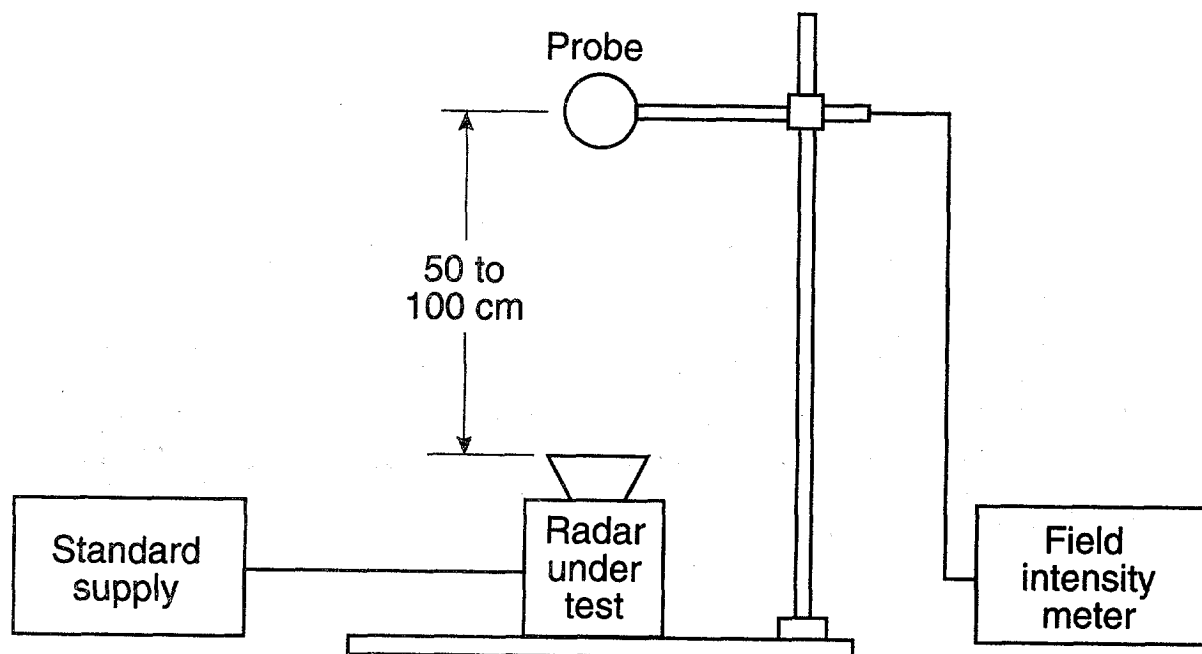


Figure 5. Block diagram for antenna beamwidth measurements.

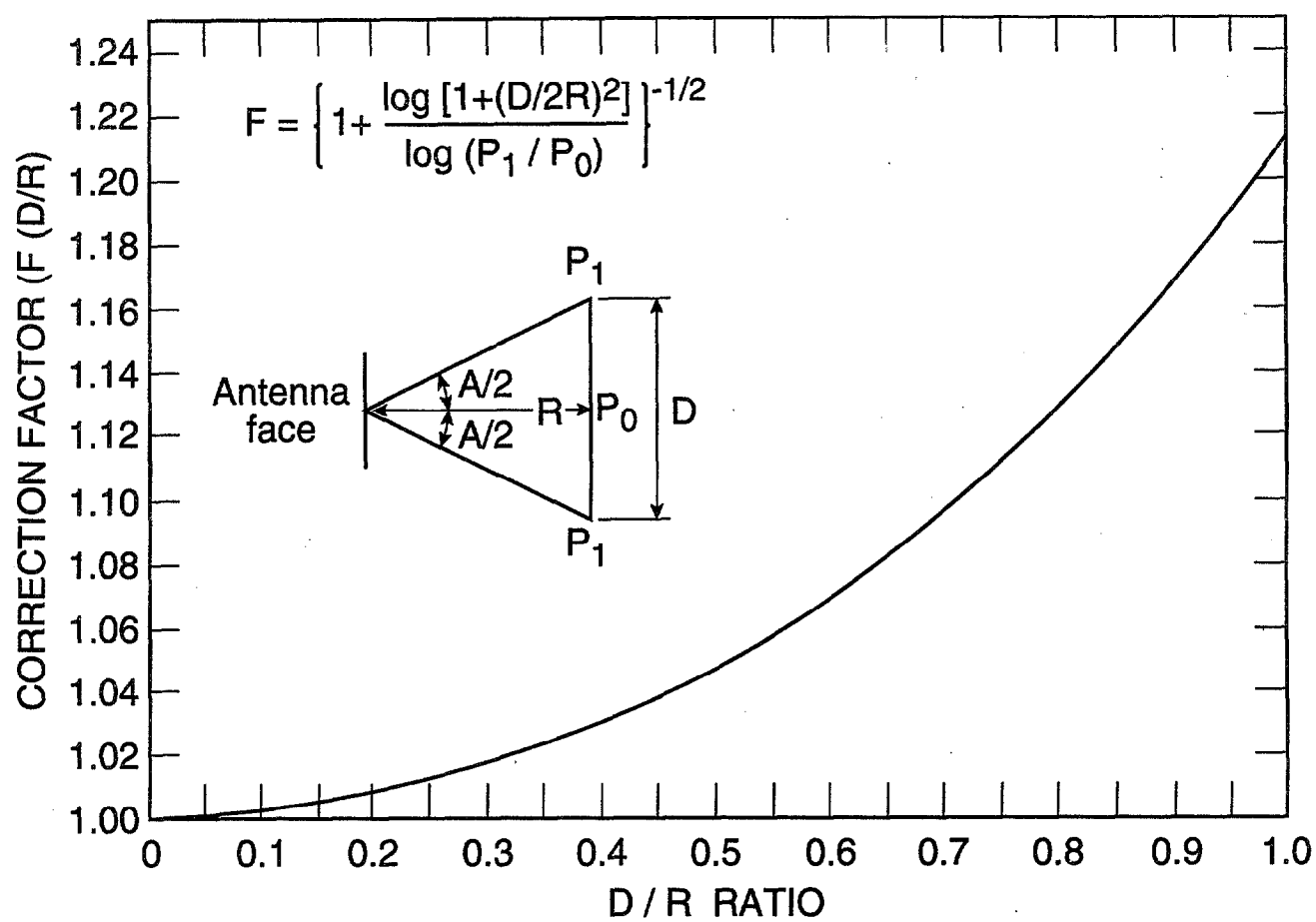


Figure 6. Antenna beamwidth correction factor, F.

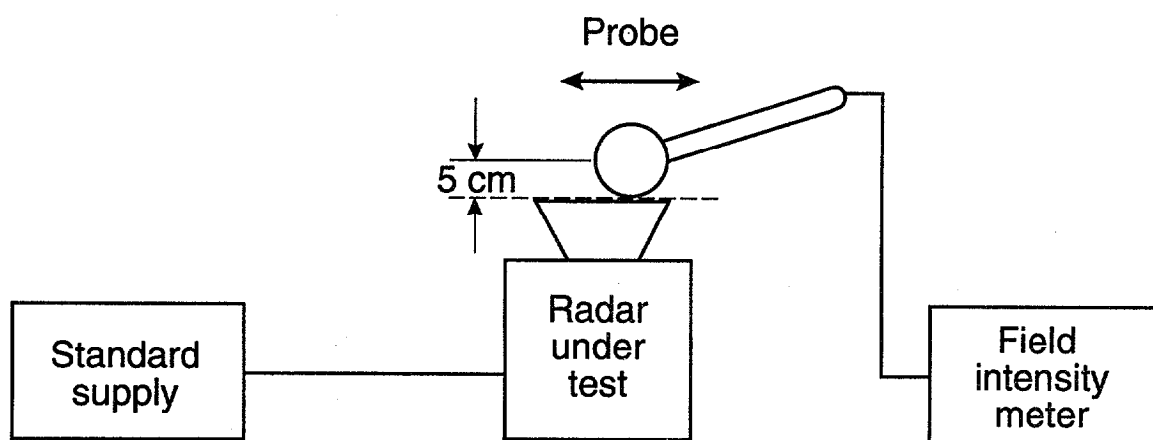


Figure 7. Block diagram for antenna near-field power density measurement.

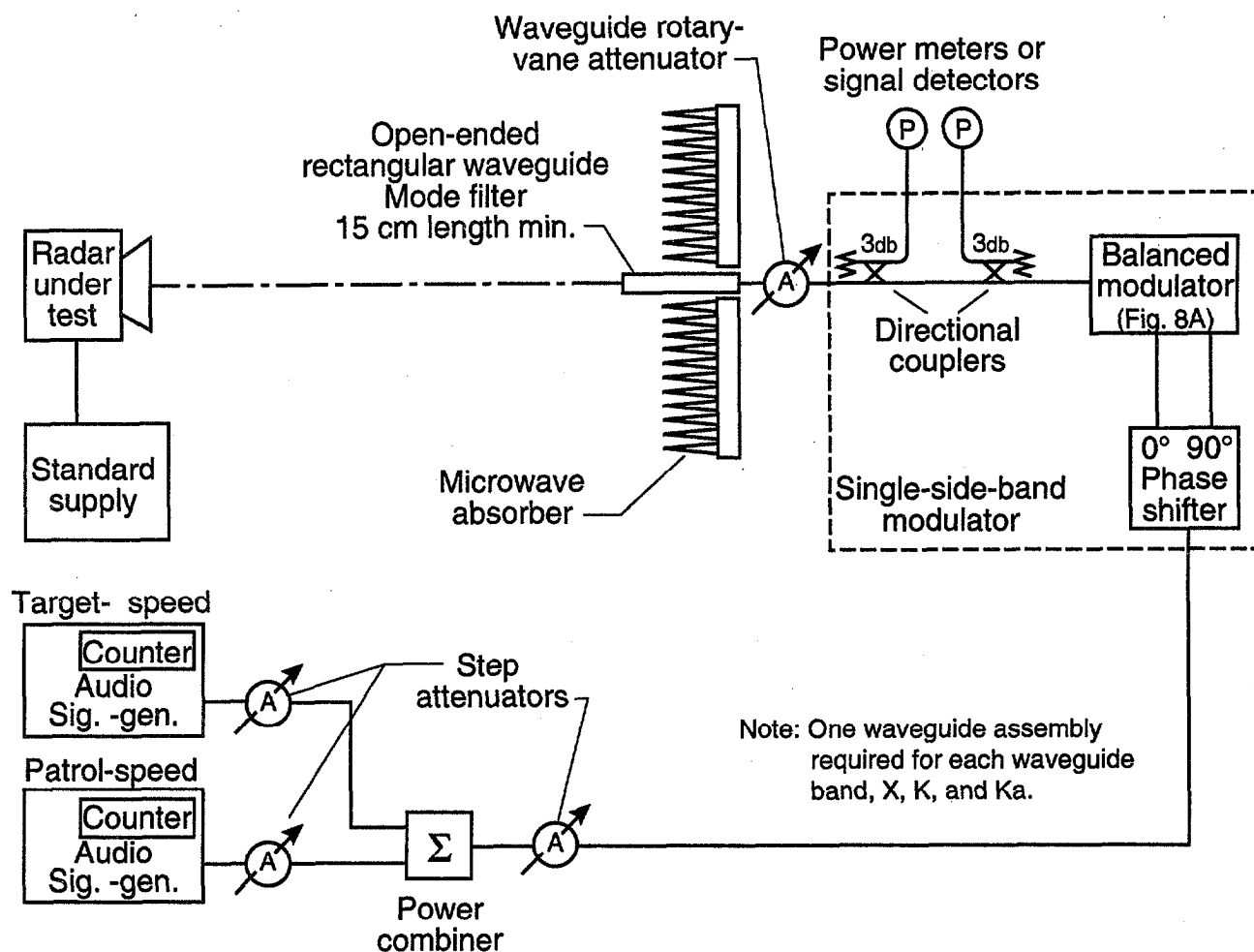


Figure 8. Block diagram for the simulator test range used in Doppler audio, power surge, speed display, and electromagnetic interference measurements.

Balanced Modulator

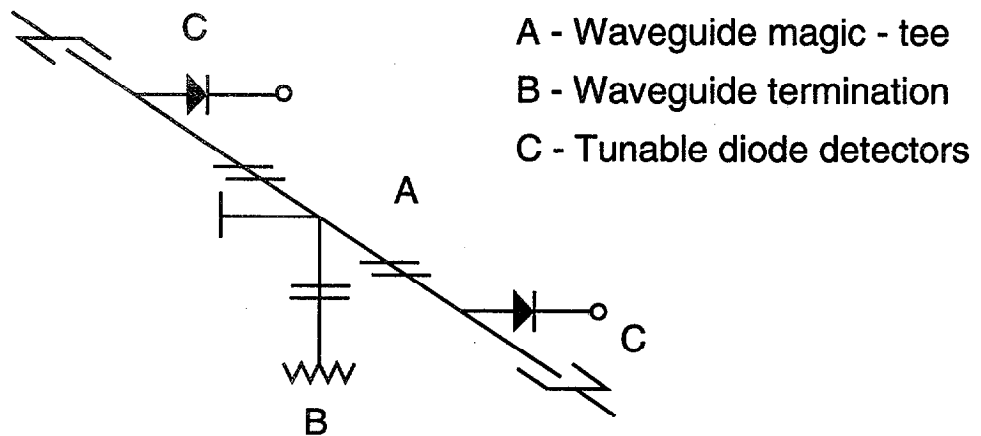


Figure 8a. Schematic of balanced modulator shown in figure 8.

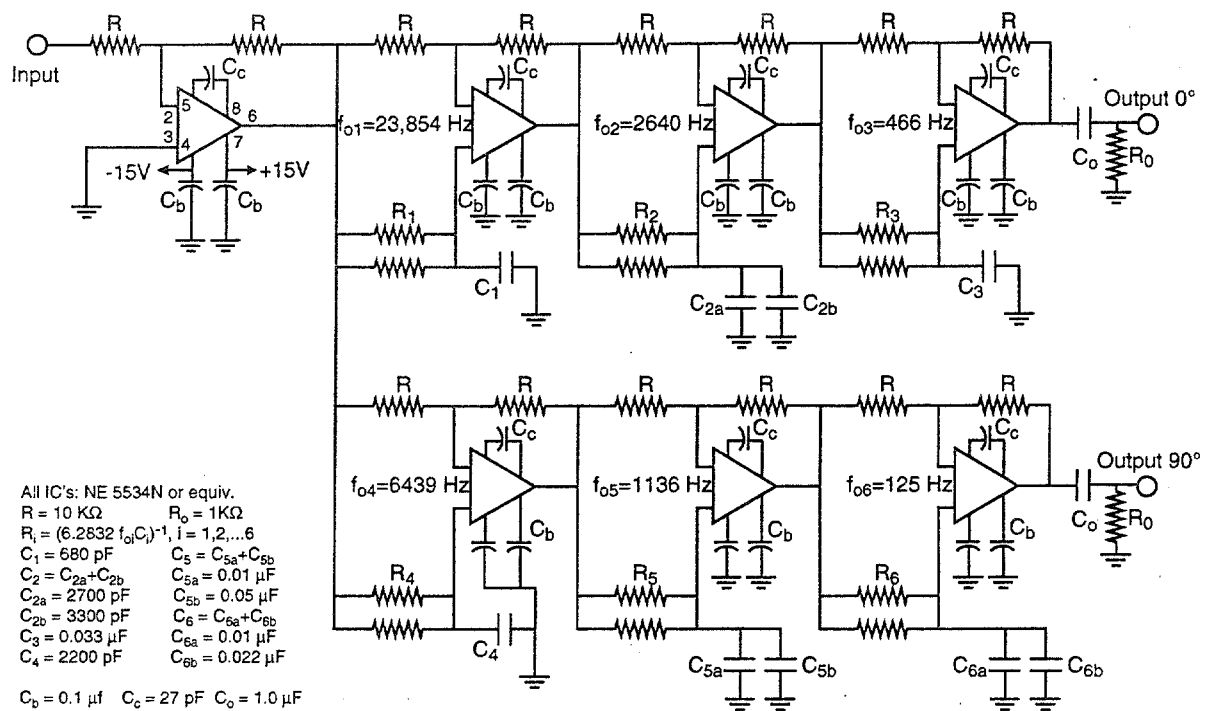


Figure 8b. Schematic of 0-90 degree phase shifter shown in figure 8.

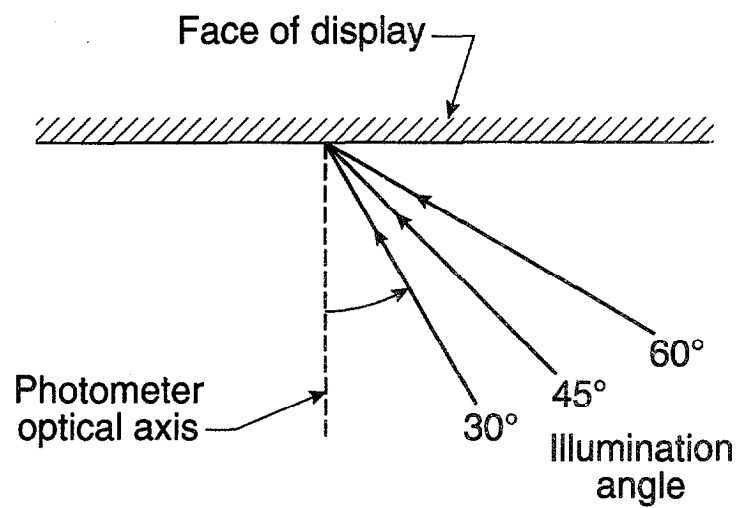


Figure 9. Setup for display readability measurements.

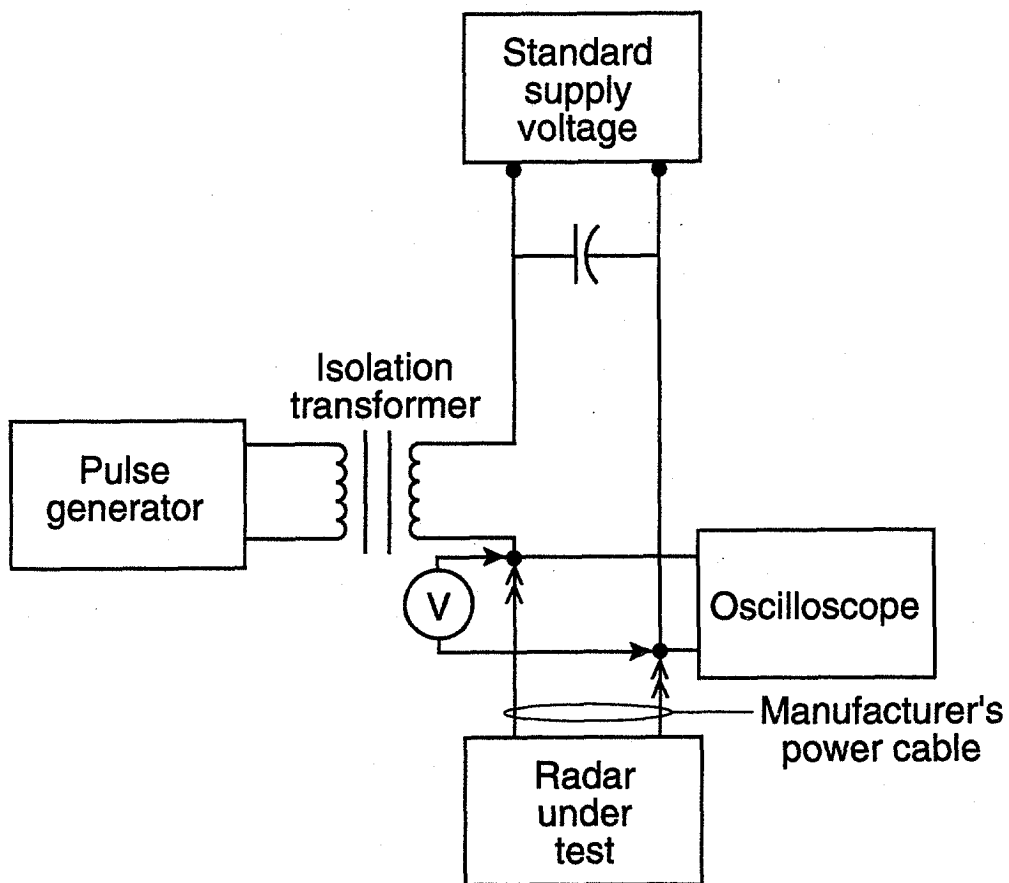


Figure 10. Block diagram for the simulated vehicle alternator interference measurement.

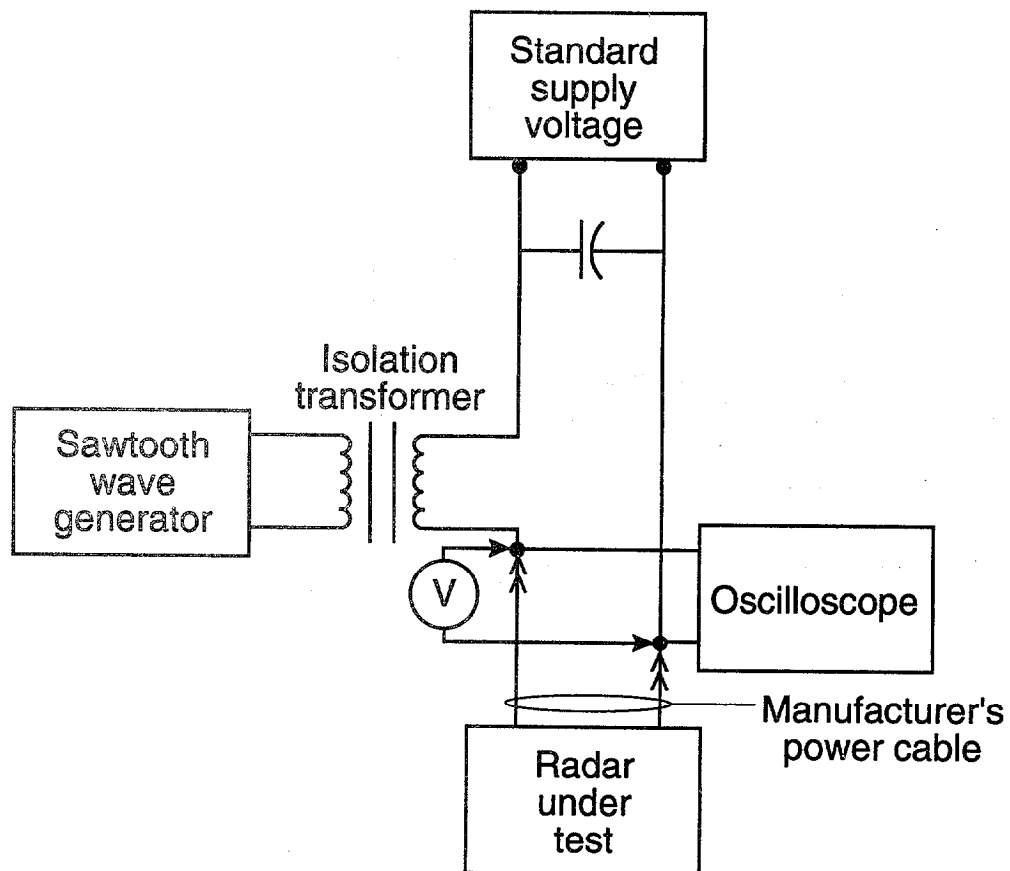


Figure 11. Block diagram for the simulated vehicle ignition, air conditioner/heater and windshield wiper interference measurements.

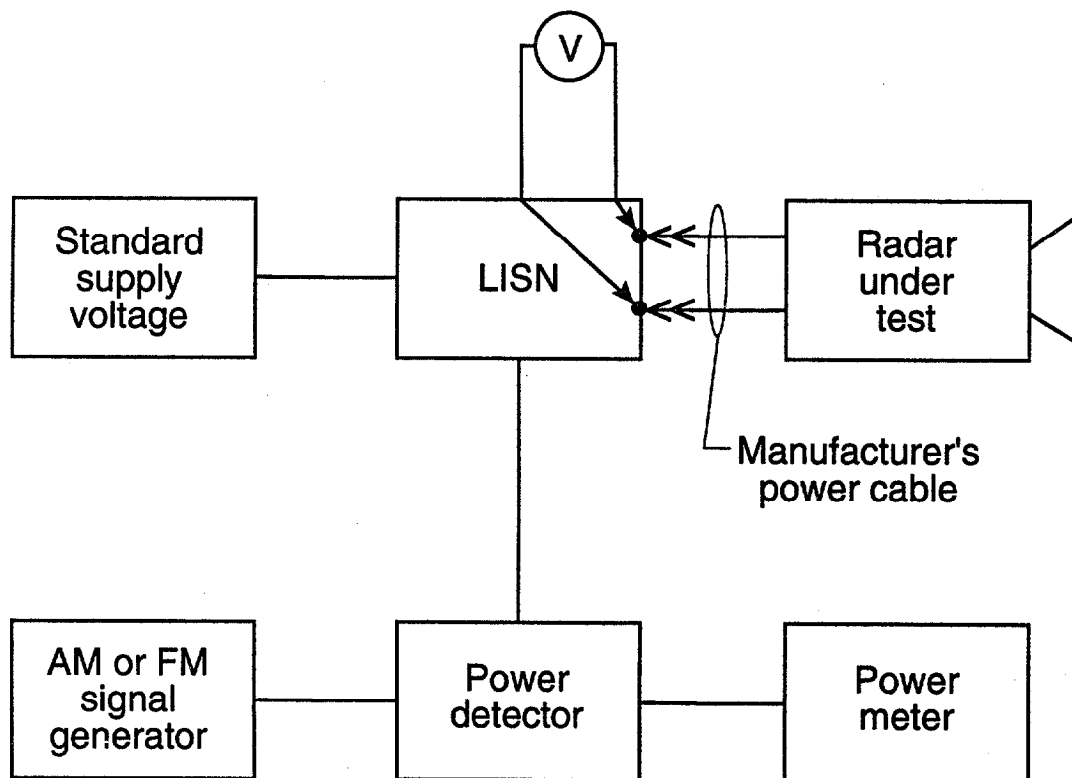


Figure 12. Block diagram for the simulated police FM transceiver and the citizens band AM transceiver interference measurements.

